Wireless Technology

Expert Report on Wireless Technologies as they pertain to Deployment and Pole Attachment Considerations

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Presented To:
Ontario Energy Board (OEB)

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Background and Introduction

On June 14, 2013, Toronto Hydro-Electric System Limited (THESL) filed an application with the Ontario Energy Board seeking an order pursuant to section 29 of the Ontario Energy Board Act, 1998 that the Board refrain from regulating the terms, conditions and rates for the attachment of wireless telecommunications devices (Wireless Attachments) to THESL's utility poles.

As part of the formal process, the Ontario Energy Board (OEB) retained Nordicity to act as wireless technology / telecommunications expert. In addition to providing expert advice to OEB staff on wireless telecommunications issues, Nordicity was also requested to prepare a standalone expert witness report with respect to wireless network technologies, with particular attention to the role of pole attachments in wireless networks.

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1. Methodology

1.1 Methodology related to creation of this report

In accordance with the scope of work agreed upon with OEB, Nordicity's general approach consisted of:

- Independent assessment of technologies used in the provision of telecommunications services, particularly wireless, which may make use of utility poles; and,
- Assessment of expert evidence.

As it pertains to this specific proceeding, the principal technologies under consideration include small cell and Wi-Fi technologies as well as distributed antenna systems (DAS). From a technical perspective, the successful completion of this proceeding will rely in part on a firm understanding of the evolutionary trends of these technologies, and also an assessment of their importance in coming years. The ability for carriers to deploy these technologies using different infrastructure, be it their own or a 3rd party, will be investigated.

In this report, Nordicity will not only carry out an analysis and assessment of THESL's pre-filed expert testimony, but also undertake additional primary and secondary research to report on the state of these technologies in the market today, as well as in the future. Research was undertaken to better understand the trends and activities taking place in other comparable jurisdictions.

Acting as an independent expert witness, the information contained in this report is prepared with no prejudice, and with no end result in mind. The report is technical in nature and meant to reflect the realities of today's communications industry, and trends which may follow in the future.

2. Current Status of Proceeding

At the time of writing this report, the OEB proceeding is already underway. A tentative schedule has been created, including specific dates set aside for what are known as the Issues Conference, Issues Day, a Technical Conference, and Expert Conference. Interveners as well as Observers have made their applications to be part of this proceeding, and an oral hearing was requested. As part of their actual application, THESL submitted pre-filed evidence, which is described below.

Also, because the Issues Conference and Issues Days have passed, we will briefly explore what was determined in these sessions as they pertain to this report.

2.1 Pre-filed Evidence of THESL

As part of its pre-filed evidence, THESL filed two reports as supporting documents to its application to the OEB. The first report (authored by Jeffery Church, Professor of Economics at the University of Calgary) presents the economic/market power argument regarding the potential shift in competition accompanying forbearance (referred to as *the Church Report*).

The Church Report is beyond the scope of the research being undertaken for this specific report, and will not be examined or referred to in any context. A second expert witness has been retained by OEB specifically for this purpose, and therefore the Church Report will be addressed there.

A second report (authored by Charles Jackson, Electrical Engineer PhD MIT, Consultant and Adjunct Professor at George Washington University) presents wireless infrastructure information and reports on four questions regarding coverage challenges, technologies in use, and the necessity of access for future network building and expansion by carriers (hereafter referred to as *the Jackson Report*).

While this report has been created as a standalone expert witness report, it will nonetheless make reference to the Jackson Report in the context of supporting evidence and to identify areas of concurrence in any issues being explored. In addition, Section 3 of this report will also make specific commentary regarding this pre-filed evidence.

2.2 Outcome of Issues Conference

On the 13th of January, 2014, the OEB held the Issues Conference at their headquarters. The purpose of this conference was to allow all the various parties to this proceeding to gather together to discuss, and attempt to arrive at a conclusion as to what the specific issues in question were for this hearing. There were three main categories for these issues; 1) Technology, 2) Competition, and 3) General.

The latter two categories are not of interest for the purposes of this report, and will therefore not be summarized here.

With respect to the technical issues, the following list was agreed on by all the parties present:

1. What is the current and likely future state of modern wireless networks?
2. For the technical operation of a modern wireless network, are there certain kinds of wireless network elements for which pole access is an option?
    a. For each such element, what purpose(s) does it serve and/or for what services and applications is it used?
    b. For each such element, are there siting alternatives to pole access?
    c. For each such element, are there technological alternatives?
3. For each of the elements discussed in Issue 2, is there an expectation that this is likely to change in the foreseeable future?

While this report will use these 3 subject areas to guide the development of the subject matter, it may also extend into other areas in order to paint a more complete picture of the various issues being examined.

2.3 Usage of this report

As mentioned, there are 2 separate expert witnesses that were retained by OEB for this proceeding. As a result, it is our understanding that both expert witnesses will be creating their own reports. This particular report, being technical in nature, is intended to be read on its own as a background document into the technologies that are under discussion in this proceeding. It is understood that the other expert witness can, and likely will, make use of the information presented in this technical report.

This approach and arrangement appears to be similar to that which was used by the expert witnesses retained by THESL in the creation of their pre-filed evidence. While this report will draw no inferences with respect to the competition aspects of this issue, it is clear that when examining the economic and competitive issues, it will be important to understand how wireless networks function, and what the requirements are for various siting options. For that reason, this report will focus purely on the technical aspects, and provide empirical evidence where appropriate to describe the deployment of equipment.

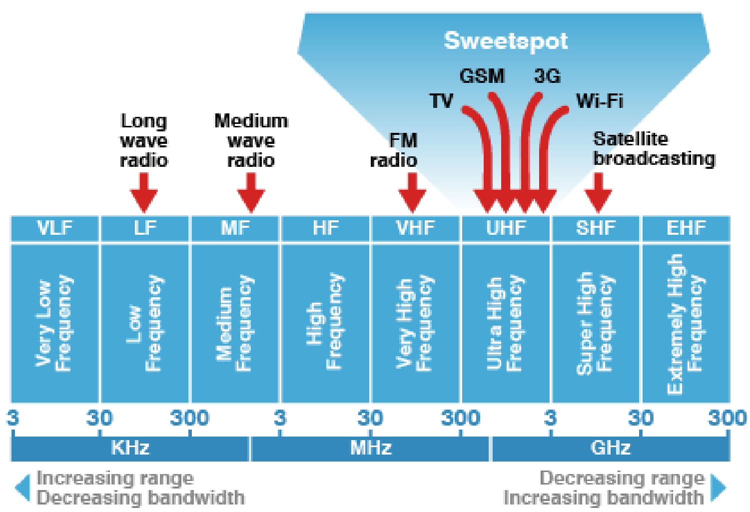
3. Wireless Network Overview

In order to properly examine this issue, it is important to ensure that the essential components and operation of various wireless networks is understood. In this section, we will explore the various types of wireless networks that are generally being deployed, as well as discuss some of the trends and changes that may take place in the near future. As this report is targeted towards a broad audience, the terminology used, and concepts being examined will be discussed at a relatively high level, focusing on concepts and services, rather than the detailed technical explanations.

3.1 Commentary on radio spectrum

In order to provide some clarity on the terminology used, we will now explain radio spectrum at a high level. The unit of measurement used for spectrum is known as the Hertz (Hz). The overall *range* of useful spectrum is from around 3,000 Hz (3 kHz) all the way up to 300,000,000,000 Hz (300 GHz). However, the radio spectrum that is actually useful to wireless networks, television, and radio signals is a much smaller range, from about 30 MHz to 30 GHz, as illustrated in Figure 1. Each specific spectrum value is also referred to as a *frequency*. For example, if you listen to an FM radio station at 101.1 FM, you are actually using equipment to tune into the frequency of 101.1 MHz.

Figure 1 - Illustration of relevant radio spectrum used in wireless networks



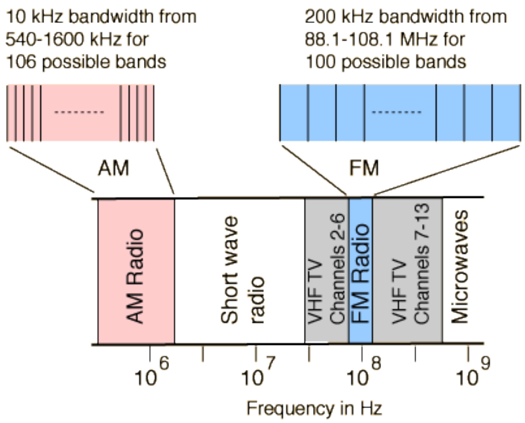


Figure 2 - Illustration of AM and FM bandwidths

Another term often used is bandwidth. This refers to the actual range of frequencies which are used to deliver a signal. Continuing with our radio analogy. An FM radio station has a bandwidth of 200 kHz. For a station that is broadcasting at 101.1 MHz, they are actually occupying (or licensed to use) the frequency range from 101.0 MHz to 101.2 MHz, with the strongest part of their signal at the mid-point, which is 101.1 MHz, as illustrated in Figure 2.

When we talk about different frequencies being used for cellular networks, Wi-Fi networks, and other wireless networks, each of these operate on a different range of frequencies. Each of these frequency ranges has their own unique properties, with some being able to travel greater distances, while others are better at penetrating walls and other obstacles. This is the reason that you may have experienced cell phone calls getting dropped when in an elevator, or losing the radio station you were listening to in a car while going through a tunnel.

In Canada, all spectrum usage, allocation, and licensing is overseen by Industry Canada[1], who in turn co-ordinates on a global level with the International Telecommunications Union Radiocommunication Sector (ITU-R) on the use of spectrum[2].

As discussed generally above, all wireless networks rely on the use of radio spectrum, some of which is licensed, and some of which is unlicensed. In the case of licensed spectrum, the spectrum itself is leased or owned by a license holder, which generally specifies a geographic region in which that license holder is entitled to operate equipment using the particular frequency which they hold the license for. No one

[1] For full details on the use of spectrum in Canada, please see http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf01678.html

[2] ITU-R main website: http://www.itu.int/en/ITU-R

else can operate in that frequency range, nor can they willingly cause interference to the license holder in that frequency.

By contrast, unlicensed spectrum is precisely the opposite. Anyone is entitled to use that spectrum, and must accept that there may be interference present where they are using that frequency range. This is one of the primary reasons that *commercial* operators are more likely to favour the use of licensed spectrum, as they have a higher likelihood of being able to deliver reliable service. It should be noted that even within unlicensed spectrum however, there are limits to what can be done, including the power levels that can be used (which has a direct impact on the range of such devices).

Regardless of the kind of spectrum in use, it is worth noting that spectrum is, by its very definition, a *limited, finite* good. Unlike things such as phone lines or power lines, you cannot add more spectrum in a region where you need more capacity. This forms the basis for an examination on what wireless network operators can do to make their services better (or offer new services). This is an area where pole attachments play a role, and will be examined further in this report.

3.2 Basic types of wireless networks / systems

The term wireless networks introduces some ambiguity regarding the specific technologies being used. Strictly speaking, any service making use of radio spectrum can be referred to as 'wireless'. However, as a practical matter, there are a few broad categories of wireless networks and systems that are generally understood to provide specific services, and are more relevant to this report. These include:

1. Mobile wireless (cellular) networks – these are the types of networks and equipment used to provide communication services (e.g. voice, data, text) to users who may be moving. This is best understood as services used by smartphones, cellular phones, cellular-connected tablets, etc. Mobile wireless networks operate using *licensed* radio spectrum. These networks are generally operated by established telecommunications carriers with subscribers paying for access to the networks.

2. Wi-Fi Networks – Closely associated with mobile wireless networks are Wi-Fi networks. These can exist in a variety of settings, such as within a home, commercial establishments (e.g. restaurants, malls, cafes), or in businesses. They are generally used to provide data wireless connectivity to high-speed wired data connections (e.g. Internet access services). Wi-Fi networks are also often used to supplement / complement the coverage of mobile wireless networks, as most smartphones, tablets, etc., can make use of both mobile wireless and Wi-Fi networks. Wi-Fi generally has a much smaller coverage area than cellular networks, operates at lower power levels, and operates on *unlicensed radio* spectrum. These networks can be private, or operated by small businesses, or even large carriers (for example, Shaw, a major ISP in western Canada, operates a Wi-Fi network to increase broadband service coverage for their customers[3]).
3. Fixed wireless networks – In certain scenarios, it is desirable to use what is known as fixed wireless networks, which are used to provide data connectivity between two points that are not moving. Examples include the provision of rural broadband in a community, or building-to-building connections in a campus or urban environment. There is a wide variety of fixed wireless network types, which can make use of either *licensed or unlicensed spectrum*. Again, these can be operated by small operators or major service providers. In more rural areas, fixed wireless networks can be used to provide broadband Internet access.
4. Others – The first three categories are the ones under the most scrutiny in the context of attachment to utility poles at the present time. However, there are numerous other network types that exist, such as satellite network systems, Bluetooth networking, near-field communications. These are beyond the scope of interest and will not be described in detail.

Within each of the broad categories, there exist many different types of actual networking equipment that can be used to provide specific services. As a part of

[3] For more details on the Shaw implementation, please see http://www.shaw.ca/wifi/

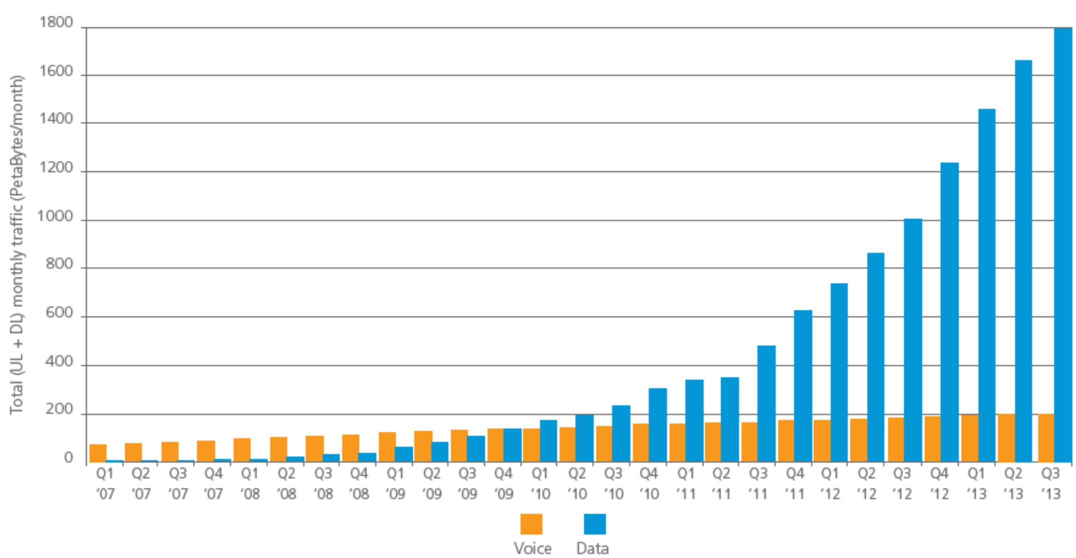
regular network evolution, these types of equipment, their size, their ability to offer specialized services, etc., are continually changing. An exhaustive investigation into every possible type of equipment used in these networks would not be practical, nor would it inform readers of the most relevant equipment to consider. As such, in Section 4 below, we will focus on the general concepts, and what types of equipment are most relevant when discussing attachments, and more specifically, pole attachments.

The following section will provide further refinements to the above descriptions of wireless networks, exploring in more depth some of the specific equipment and developments that are taking place in these categories of wireless networks.

3.3 Current state of wireless networking

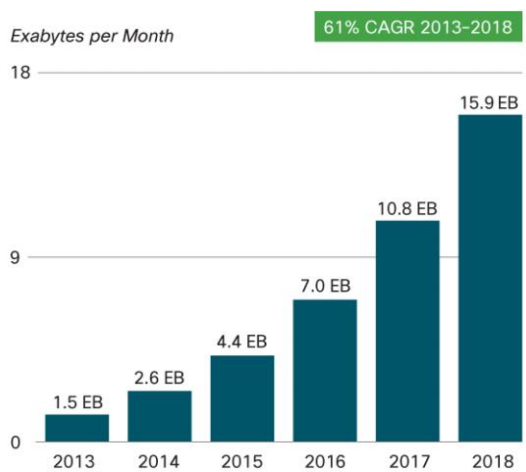
If you are reading this report on a laptop or a tablet computer, the chances are very good that you are using a wireless network. There is no doubt that wireless network adoption and usage has grown by leaps and bounds over the last two decades in particular. People have come to rely on mobile wireless devices and access to services such as mobile cellular and Wi-Fi connections to help them be more productive and to stay in touch and interact with the world around them.

Figure 3 - Growth of Mobile Data Traffic over Time (Akamai / Ericsson)



As a small illustration, Figure 3, taken from a quarterly report by Akamai (a provider of content delivery services) on the current state of the Internet, shows the rapid growth of mobile data since 2007[4]. The blue bars are a remarkable illustration of the growth of mobile data traffic in just 4 short years. Whereas mobile voice traffic used to be the key traffic component of mobile wireless traffic, it only represents about 10% of the overall traffic volumes now.

Figure 4 - Global Mobile Data Growth (CISCO)



In another annual report produced by CISCO (a telecommunications equipment manufacturer), predictions are made with respect to mobile data growth in the coming five years (for all mobile traffic). Figure 4 illustrates their prediction on mobile traffic growth for the period from 2013-2018[5].

While both of these charts illustrate global figures, the North American market on its own exhibits the same growth rates as its international counterparts.

There are two main reasons for this growth in mobile data traffic. The first is the availability and adoption of devices, and the second is the increase in the availability of applications and services that can be used on these devices. In the most recent CRTC Communications Monitoring Report, data was shared regarding the adoption of various mobile devices from 2009 to the present. This is shown in Figure 5 below. What the image is telling us is that cellphone penetration has now reached 80% in Canada. Looking at the data one layer deeper, we see that fully 50% of Canadians

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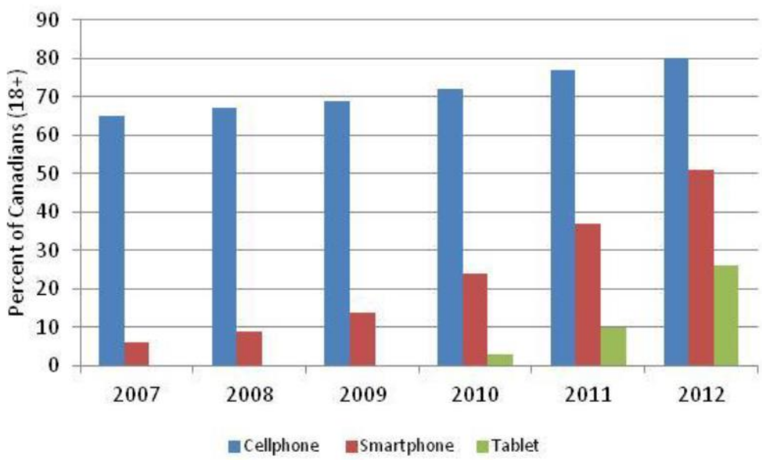
[4] Updated quarterly, the Akamai "State of the Internet" Report is a valuable resource for examining current trends in online consumption. Reports can be found here: http://www.akamai.com/stateoftheinternet/

[5] To access the latest Global Mobile Data Traffic Forecast report, please refer to: http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html?CAMPAIGN=MobileVNI2014&COUNTRY_SITE=us&POSITION=sl&REFERRING_SITE=cisco%2Ecom+homepage&CREATIVE=MobileVNI+2014+Cisco%2Ecom

identify themselves as owning not only a simple cellphone, but a smartphone (such as Apple's iPhone, Blackberry Devices, or phones using the Android operating system). Additionally, tablet penetration has now passed 25%, which is a remarkable

Figure 5 - Canadian Mobile Device Penetration (CRTC / MTM)



Source: MTM 2012 (Respondents: Canadians 18+)

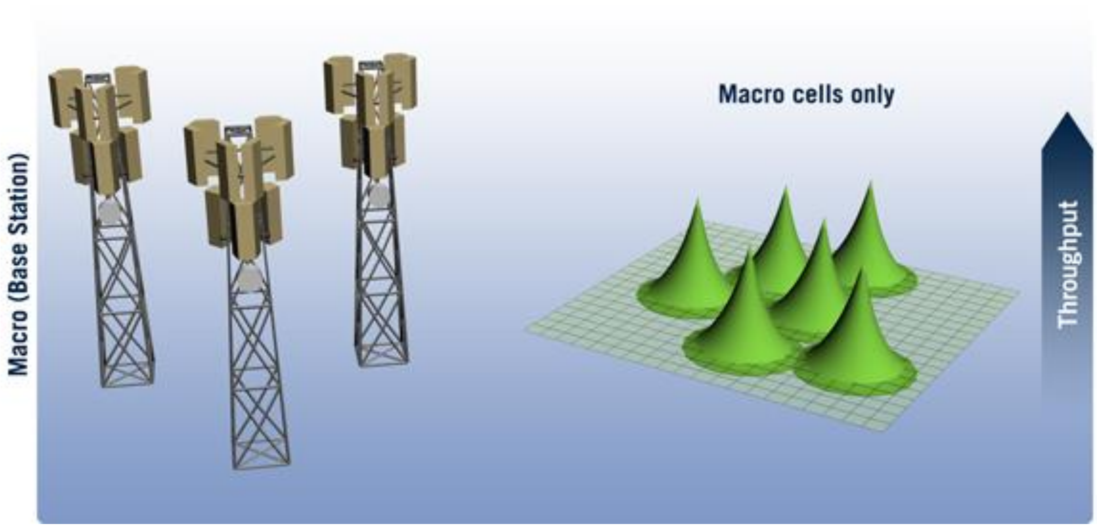
feat in 3 short years.

As can be imagined, the growth in demand for both devices and services has led to pressure on service providers in the context of building and maintaining networks capable of handling this growth. One area of particular importance is the ability to build and operate additional equipment sites where antennas and other equipment are placed. These are used to provide the services that people have come to depend on. For service providers, the key to increasing the capabilities of wireless services is two-dimensional. A provider must increase both capacity AND coverage. Capacity is the ability to carry greater amounts of data, while coverage is the ability to carry these greater amounts of data in more places, at all times.

In the previous section, we established that while spectrum is the key commodity in being able to provide services, it is a finite good. Without being able to add spectrum, this leaves service providers the requirement of adding network equipment in smaller geographic areas, which in turn increases the capacity available in that area. Simultaneously, increasing the volume of these deployments leads to increased coverage as well.

In the context of mobile data networks, these needs are what is driving the move towards what is known as small cell deployments, and to a lesser degree, the use of distributed antenna systems (DAS). In broad terms, a small cell is essentially a smaller version of the cellular equipment being used to provide services today. If we were to describe the main technologies, or cell types in use today, the basic building block of mobile wireless networks is known as a macro cell. These types of equipment provide the greatest geographic coverage, and the highest power output, and are what you will see on towers throughout the world to offer mobile wireless services. The image below represents the type of coverage that is achieved with a macro cell[6]. The shape of the green cones represents the strength of a signal a user would be able to receive at any particular geographic point; the closer to the tower, the stronger the signal, and hence the greater the volume of data it can handle in that area.

Figure 6 - Macro Cell Coverage



Macro cells are generally the first pieces of transmission equipment deployed and used by service providers to deliver mobile wireless services to their customers. Macro cells, and their associated towers (when mounted to towers), have become a fairly contentious issue for a number of reasons, including aesthetic concerns raised

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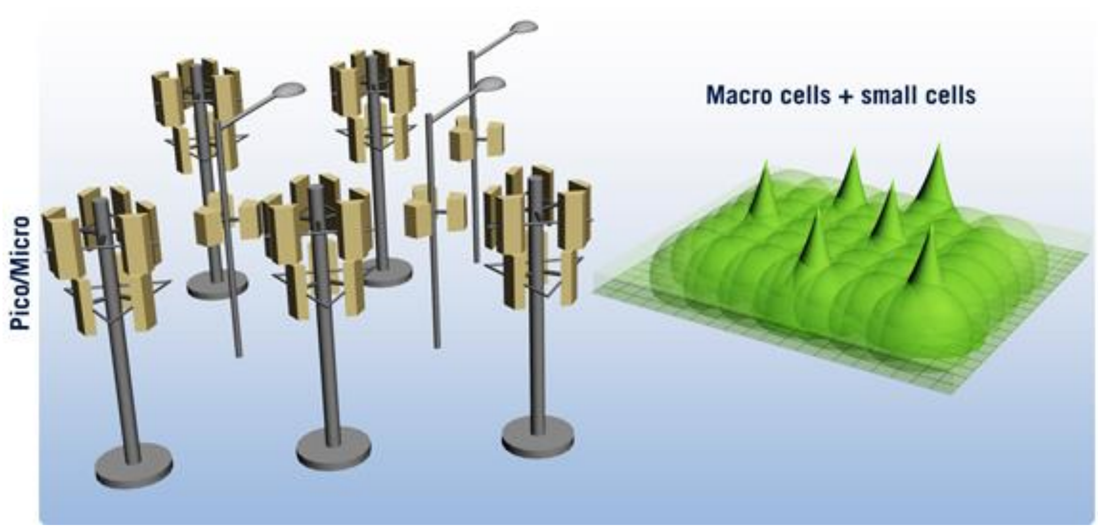
[6] Image reproduced from an online article regarding the role of small cells found here: http://electronicdesign.com/4g/understanding-small-cell-unification-s-vital-role-lte-and-4g

by having too many towers erected in communities. This has recently prompted the federal government to modify rules related to constructing new towers[7]. The new rules require network operators to carry out a public consultation on the possible construction of any new towers, regardless of their height.

This change in rules may prompt service providers to seek increased usage of alternatives to macro cells, which brings us to the second type of wireless transmission equipment, referred to as small cells. These small cells are used to help ‘fill in’ the coverage of the macro cells in certain areas. In Figure 6, we saw that there are areas that have less capacity, as depicted by the cone shapes. The higher the peak, the greater the volume of traffic that can be handled at a given point in space. Contrast this image to that shown in Figure 7, which illustrates the role that small cells play for increasing capacity *and* coverage in mobile wireless networks.

Figure 7 - Coverage when Macro and Small Cells are combined



As can be seen in Figure 7, the overall coverage is more uniform over the given geographic area of coverage. This deployment scenario allows a service provider to deliver greater volumes of data to more people in the same geographic area as they could using only the macro cell infrastructure. Earlier, we also made mention of DAS technology. There is a well-written description of DAS in the Jackson Report, as part of the pre-filed evidence of THESL, found beginning on page 13 of the Jackson

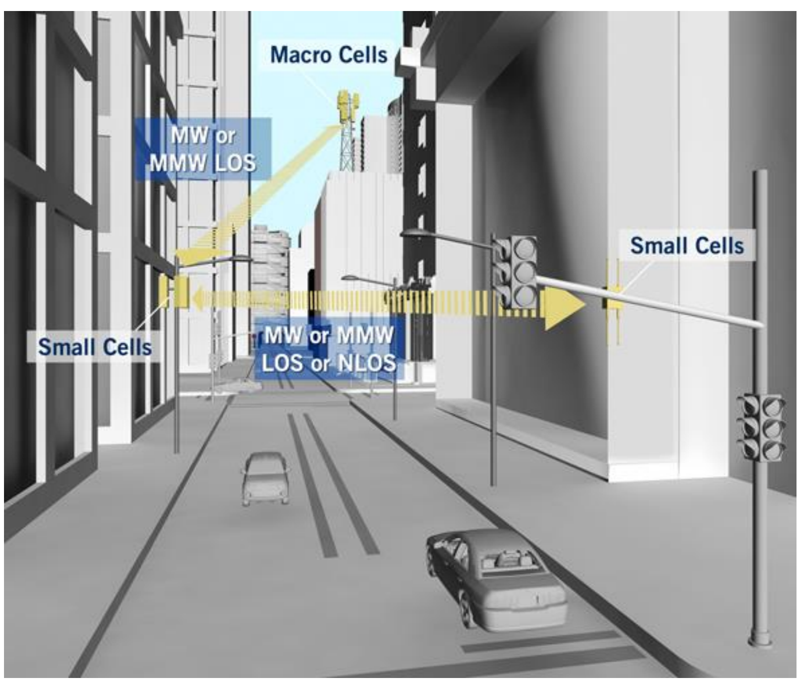
[7] Industry Canada webpage related to cell towers: http://www.ic.gc.ca/eic/site/icgc.nsf/eng/07422.html

Report, in section 3.4.4. For the remaining discussion in this report, DAS deployments serve the same practical purpose as small cell deployments, and have similar considerations. The principal difference between small cell and DAS deployments is that with a DAS system, there are multiple antennas (in different locations) connected to the same base station. Therefore, a DAS system may provide greater geographic coverage (through the multiple antennas), but less overall capacity (as it is shared by a single base station) in that area.

To complete the investigation into the principal categories of mobile wireless networking equipment, and to put it into the context of an urban setting, it is worthwhile to once again use an illustration to clearly show how these technologies are deployed and used in downtown cores.

Figure 8 shows the typical scenario in a city centre. Without venturing too deeply into the acronyms being used, in this diagram, LOS stands to line-of-sight (meaning equipment needs to be able to 'see' what it is sending data to) and NLOS stands for non-line-of-sight (meaning the transmission can pass through obstructions). There is also reference to microwave (MW) and millimeter wave (MMW) technologies, which are simply ways to send the data between equipment.

Figure 8 - Representation of small cell and macro cell deployments in urban setting



Note about Wi-Fi Deployments

While technically a gross over-simplification, for the purposes of keeping things relatively straightforward, we invite the reader to consider Wi-Fi deployments to be similar to small-cell (and DAS) deployments. We assume this simply because both small cells and Wi-Fi deployments utilize low-powered equipment intended to provide coverage and capacity to relatively small geographic areas. As we will discuss further in this report, they are also both capable of being deployed indoors and outdoors. The principal difference is that Wi-Fi networks are often operated as either single pieces of equipment offering network coverage for a single business for example, or they are offered for providing limited data connectivity in a constrained region. As mentioned earlier, Wi-Fi makes use of non-licensed spectrum, and therefore is operated under different business models than mobile wireless networks.

3.4 Near-term developments in wireless networking

Now that we have examined the growth of wireless traffic, as well as some of the equipment most prevalent in wireless network deployments of today, it is important to understand what near-term changes and shifts may take place in this industry. As illustrated above, we have seen that consumers are increasingly adopting devices that make use of wireless networks (both cellular and Wi-Fi). However, there is a second, and growing market segment also making use of these same networks. This segment is known as machine to machine (M2M) communications, sometimes also referred to as the 'Internet of things'.

There are a number of definitions with respect to M2M. One of the more concise definitions can be found in an article on the website Howstuffworks[8]. In this article, they define M2M in the following way:

> *"In machine-to-machine communications, a remote sensor gathers data and sends it wirelessly to a network, where it's next routed, often through the Internet, to a server such as a personal computer."*

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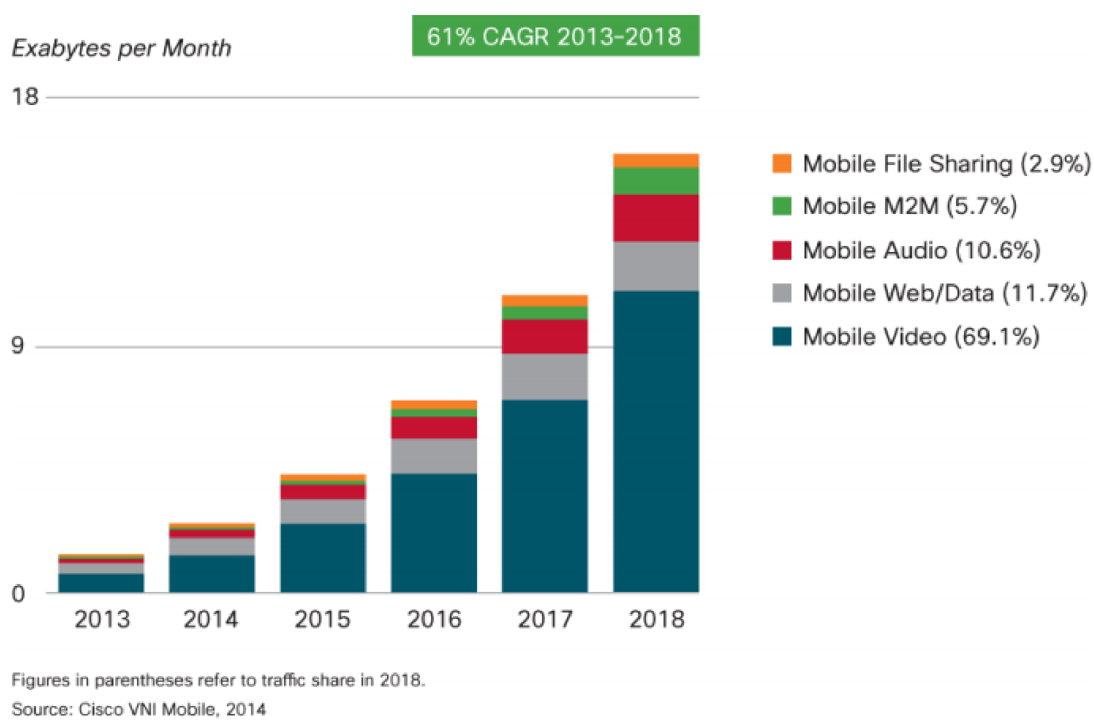
[8] For a reading of the complete article on M2M communications, please see: http://computer.howstuffworks.com/m2m-communication.htm

Phrased another way, one can think of M2M communications as being a conversation between two machines rather than two people (e.g. voices calls, texting, instant messaging) or between people and machines (e.g. web browsing, streaming audio, streaming video).

Earlier in this report, we examined the growth of mobile traffic over the next 5 years, as forecast by CISCO. This included all mobile traffic, including the contribution of M2M traffic to this forecast. Figure 9 below further stratifies mobile traffic volumes and growth by specific type, including M2M traffic. This forecast indicates that by 2018, M2M will make up 5.7% of all traffic.

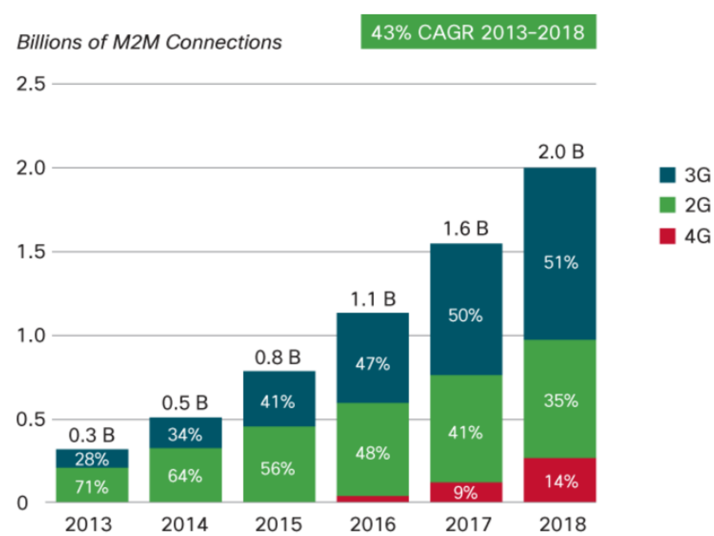
Figure 9 - Growth of Mobile Traffic by Type



One of the principle differences between M2M and other mobile data usage are the number of unique connections that can occur in comparison to the actual volume of data used. A human user streaming video, for example, will utilize a single data connection but consume a lot of data. By contrast, in M2M communications, you may have dozens of sensors, each utilizing a data connection, but each only using a small amount of data.

This growth in the number of connections can have just as dramatic an impact on network requirements as the growth of traffic volumes generated. One of the characteristics of the macro cell and small cell equipment we discussed earlier is the fact that each of them can only support a fixed number of users at any one particular time. Without getting into the technical specifics, this is a function of how the traffic is being carried, which is in essence split into 'channels' in the equipment, similar to a television signal. Each user is assigned their own channel in real-time as they use the network, and the 'right to use it' changes dynamically with time as others require access. With a limited number of channels, if too many users attempt to connect to the network (whether it is a person or a machine), some will be denied access as a result of too many concurrent users.

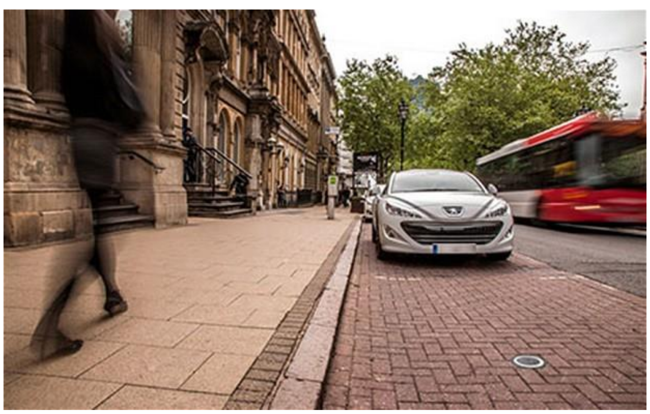
Figure 10- Growth of M2M Connections 2013-2018 (CISCO)



The solution to this problem is once again to deploy additional network equipment in smaller geographic areas. In that way, more users can connect to the network in the larger area, as there are more connection points. Figure 10 illustrates the projected growth of M2M connections over the next five years. The terms 2G, 3G, and 4G are simply references to the types of cellular network technologies, with 4G being the newest technologies (also called LTE), and 2G being the oldest technologies. The reason that older technologies are still in use going forward is the fact that as mentioned, M2M sensors don't require lots of data usage, so they work just as well on older technologies. As an analogy, imagine a computer user mainly interested in simple email. They *could* purchase and use the latest and most expensive computer to do this, but in reality, a 5-year old computer can just as easily be used for this purpose. The goal of M2M adoption is to make it as economically attractive to use as possible, which means in part using older network technologies to 'get the job done'.

There are a wide range of applications that can make use of M2M communications. As a partial list, M2M can be used in areas such as home and office security and automation, smart metering and utilities, maintenance, building automation, automotive, healthcare and consumer electronics[9]. While low-bandwidth applications are more prevalent, there are also a growing number of bandwidth-intensive applications such as video-based security systems to help companies with monitoring, and even remote monitoring of patient progress used by hospitals and healthcare professionals.

Figure 11 - Image of sensor embedded in London road



Examining these M2M developments from an urban perspective, there are a number of M2M applications that are beginning to be used in downtown cores. One example, which has been under trials and deployment in other parts of the world is what is known as smart parking. Using a network of sensors embedded in a roadway, which are connected wirelessly to other equipment, drivers are able to look up where parking is available in a congested downtown core. A recent article (January 2014) in the Telegraph, a British newspaper, explains how such a system is being trialed in the west end of London[10]. As part of this project, the Westminster Council first undertook a pilot project with 189 roadway sensors, and are now in the process of deploying 3,000 sensors. There is even speculation that an additional 7,000 sensors may be added in the next few years. Smart parking systems

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[9] For a more comprehensive list, and an excellent overview of M2M in general, ZDNet (a technology news website) has an excellent series of stories, including this one: http://www.zdnet.com/m2m-and-the-internet-of-things_p2-7000008219/

[10] For full article, please see: http://www.telegraph.co.uk/technology/news/10573651/Smart-parking-app-begins-rollout-in-Londons-West-End.html

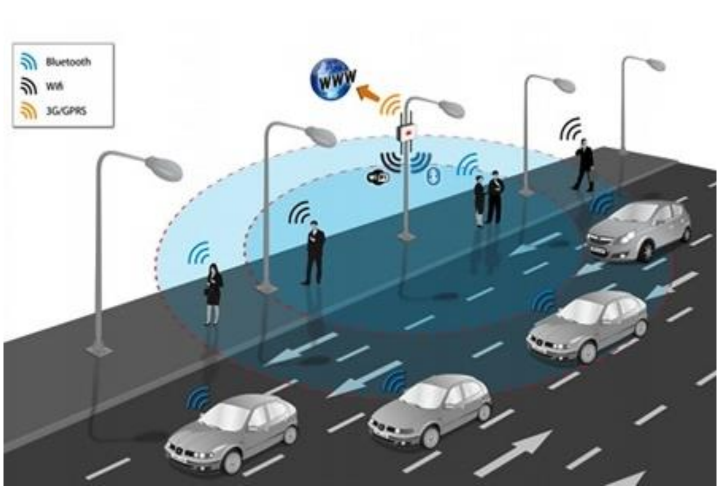
make use of either smartphone apps to let users know where parking is available (via a map image), or through signs that indicate the number of parking spaces available in a given area.

Applications such as the smart parking example will be increasingly looked at by municipalities and private companies alike to deal with traffic, parking, and security issues downtown. There are a number of companies that specialize in equipment designed for use in the urban environment. Examples of other sensors that could be used for monitoring conditions include natural gas sensors, emission sensors, and temperature sensors. All of these could be used to monitor environmental qualities.

Figure 12 - Sign indicating number of spots available

All of these initiatives become part of a larger movement towards what is referred to as 'smart cities'. One company specializing in this area is Libelium[11], and they have a wide range of equipment and usage suggestions for creating these smart cities.

Figure 13 - M2M Sensor Deployment to monitor traffic



As Figure 13 and Figure 14 illustrate, urban planners and city operations people will be able to use M2M technologies to better understand what is happening in real-time in the communities. With sensors feeding information back to a real-time operations centre, cities will be able to more efficiently allocate resources and identify problems in real

[11] To explore more about Libelium, please visit their website at: http://www.libelium.com/

time based on the information they receive. This in turn could lead to cost savings and efficiency gains for everyone.

Although adoption of these technologies is only beginning, it is an area of high growth possibilities, and as explored earlier, will lead to pressure on existing wireless networks for the coming years. While there is no way to predict what the overall impact of these developments on the networks of tomorrow, we can certainly see that recent developments seem to indicate that these are areas of high growth and adoption, and will lead to a transformation in the way cities operate in the future, through better connectivity.

Figure 14 - City traffic monitoring center

3.5 Commentary on backbone, or core networks

Before moving away from the network technologies, it is worth taking a moment to explain the role of what is known as backbone, or core networks. A wireless network can only communicate to the outside world, and/or the Internet when connected to it. We know that a user on a tablet communicates to a macro cell or Wi-Fi hotspot, but there also needs to be a connection from that piece of equipment to the main network of the service provider. We will not go into great detail on this aspect, but as will be described later, this connection can have a bearing on the deployment of wireless networks. At a high level, the equipment can be connected to the main network either wirelessly, or through wires. When wired connections are used, they can be any number of technologies, but will mainly be either fibre optics, or rely on phone lines or cable lines (copper-based connections). You may also see some connections referred to as Ethernet-based. Ethernet is simply a technical standard used for data transfer, and can utilize either fibre-based or copper-based connections.

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4. Specific Role of Pole Attachments in context of Wireless Networks

Now that we have examined the state of wireless networks, the impact of traffic growth on networks, and examined some of the high-level shifts and developments in the wireless networking space, we now turn our attention to the specific role of pole attachments specifically, and of siting options (where to place equipment) generally.

4.1 Determining where to place equipment

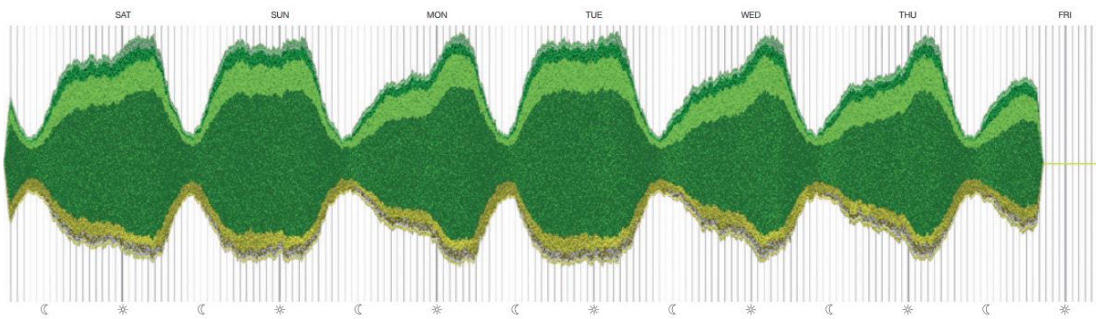
It is important to understand the method by which network designers and planners choose where to place equipment. For the purposes of this discussion, we are speaking primarily about the equipment used to transmit and receive data to/from the main wireless network. This primarily includes antennas and miniaturized base stations.

In earlier sections, we have explored the role that macro cells, small cells, DAS, and Wi-Fi equipment have in network deployments. At a high level, all are used to increase coverage and capacity, but do so in a different manner. As such, a wireless network provider, or prospective network provider, will examine the traffic expectations and subscriber numbers that they are trying to serve. Concurrently, they will need to take into consideration the volume of traffic these subscribers will generate on the backbone network, and more importantly, the specific geographic areas where that traffic will originate.

This exercise of traffic engineering is an ongoing process for network operators. They are constantly balancing and analyzing their networks to ensure that they can deliver the greatest Quality of Service (QoS) to the greatest number of customers, at any time of the day. It is worth noting that traffic volumes change throughout the day, and this must be taken into account. As you can imagine, the traffic requirements of an urban core are greater throughout the day than in the evening hours, and much greater than the overnight hours. They must also be aware of, and ready to respond to traffic surges, such as if there is a big sports event or music concert. In those situations, operators may even deploy temporary equipment.

Ericsson, a network equipment vendor, shared anonymous network data from various wireless service providers around the world with researchers at the MIT sense*able* city Lab[12], which analyzed the data and visualized the traffic patterns. One of the results is shown below in Figure 15. The peaks and troughs of this image illustrate the volume of traffic being carried by the mobile wireless network at various points of time in the day.

Figure 15 - Time of day traffic visualization for a mobile network (Ericsson / MIT)



Once network planners have an idea of the amount of traffic, and location of that traffic that they must accommodate, they will begin a detailed analysis of where they can most efficiently deploy equipment to meet those needs. To accomplish this, network planners use specialized software that can simulate the equipment that they wish to deploy, and utilize geographic information systems (GIS) to see the effects of such a simulation in the area they are modeling.

The more detailed the GIS that is being used, the more accurate they will be able to predict the behaviour of the network in different conditions. Figure 16 shows a sample screenshot from one particular network planning tool. The colours in the image indicate the level of signal strength in any given location based on the specific characteristics of the equipment being modeled. As you can imagine, items such as buildings, natural features like hills, trees, etc., all have an impact on the ability for a

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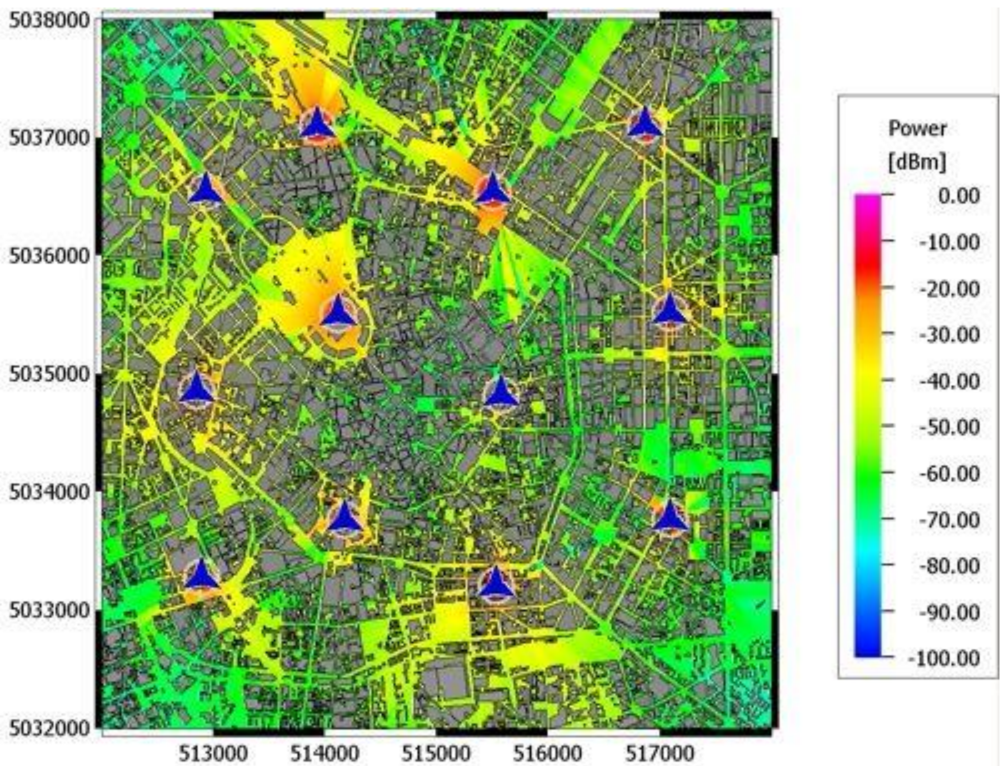
[12] Homepage for the MIT lab: http://senseable.mit.edu/ / Source of chart (June 2012): http://www.ericsson.com/res/docs/2012/traffic_and_market_report_june_2012.pdf

signal to travel between a user (a cellphone or tablet for example) to the network (a macro cell or small cell).

Figure 16 -Wireless Network Modeling Software



As previously mentioned, radio spectrum in different frequency ranges exhibits different characteristics. Without getting into the detailed physics behind this, we will simply state that different frequencies will travel different distances, penetrate buildings better, and/or interact with objects and other radio waves differently. As a result, the choice of where to put a particular piece of equipment can actually vary by the frequency being used as well. All of these various criteria mean that the final chosen location for mounting antennas / equipment will often become a process of identifying the location which has the widest application possible. For this reason, once an 'ideal site' has been determined, network engineers will seek to position the equipment as close as possible to that location.

The next step would be for network deployment specialists to examine the areas that are most suitable by examining whether or not there is easy access to power for equipment. They must also determine whether there is an ability to connect the new equipment to the existing core network through fixed connections such as fibre optics or Ethernet cables. Finally, as is often the case, negotiations will need to take place with site owners (such as the landowners, pole owners, or building owners, etc.) for access to the site.

The combination of all the above factors are what will lead a network operator to choose one site over another for installing their equipment.

4.2 Equipment Suitable for pole attachment

In an earlier section of this report we explored the difference between macro cells and small cells, as well as the role that Wi-Fi plays in the wireless ecosystem. From this early discussion, we can see that macro cells would be located outdoors. Furthermore, their overall size, space, and power requirements make them obvious candidates to be installed either on their own support structures (cell towers), or on the top of building roofs. In fact, one does not have to look very far in a downtown core to see these cell sites dotting roofs in the urban jungle. When we discuss equipment attached to utility poles, we are focusing on other categories, such as small cells, Wi-Fi nodes, as well as newer equipment such as sensors for M2M networks.

Figure 17 - Macro Cell site on rooftop

Figure 18 - Locations for small cells

On the previous page, Figure 18 is an infographic taken from company Ubiquisys (now owned by CISCO) meant to illustrate the various locations that small cells can be deployed, as well as illustrating the problems that small cells are intended to address. In the image, it can be seen that small cells, when mounted outdoors, are often attached either to the outside walls of buildings, or utility poles / lamp posts. However, the diagram also points out some of the limitations posed by such installations. One of the key messages communicated in the diagram is that one of the major uses of small cell technology is for providing cellular network coverage indoors, where studies indicate a large amount of mobile data consumption is taking place.

Figure 19 - Alcatel-Lucent lightRadio module and housing

Alcatel-Lucent, another company well known for the provision of telecommunications equipment, is also a manufacturer of small cell technology. In their product literature, they outline that this equipment can be placed in different outdoor or indoor locations. One product line is known as lightRadio[13], and they state this:

> *"Because they are small, unobtrusive devices, metro cells can be deployed in almost any location without the visual pollution caused by traditional towers. Alcatel-Lucent metro cells can be mounted easily on walls, lamp posts, poles or even the side of a building."… "Alcatel-Lucent offers a wide variety of metro cells that can cover all types of locations. They include indoor and outdoor metro cells, as well as cells that are deployed outdoors for easy accessibility, while extending coverage and capacity to indoor locations."*

All manufacturers of this type of equipment stress that there are numerous options for the placement and installation of their equipment. As explained in the previous

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[13] For more detailed information from Alcatel-Lucent, please visit their website: http://www.alcatel-lucent.com/solutions/small-cells

section, there is no single, perfect place, or way to attach and install this type of networking equipment. In fact, the flexibility of placement is what can assure a network operator of being able to offer the best combination of services to their customers.

Figure 20 - Images of various attachment options for small cell equipment

Besides the small cell technology, it is worth noting that other types of wireless technology are being promoted as being appropriate for mounting to light poles / utility poles. Sensors for M2M applications are among those that make sense for mounting in this way. In our previous example of the smart parking, the sensors that are located in the road in parking spots communicate information back to a sensor placed on a nearby light pole. In fact, it is interesting to note that some of the new equipment being explored is completely self-powered. There are sensors which include small solar panels to provide power to the equipment. In addition, the backhaul connections (the communications links back to the core network) are also provided wirelessly, so no further connections or power are required at all. An example of such a sensor deployment is shown in Figure 21 on the right.

Figure 21 - Remote sensor mounted to a pole

Referring now to the topic of 'backhaul' connections, we stated earlier that often times, small cell and other wireless equipment requires a physical connection, such as fibre-optics or Ethernet cabling, in order to connect to the main (core) network. However, there are still other technologies that aim to reduce that requirement through offering completely wireless backhaul connections as well. One example is a Canadian company (Dragonwave), which designs and produces this type of equipment[14].

One of their product lines, known as 'Avenue Link' is described as an "*urban-optimized small cell backhaul system*". Once again, the focus for this equipment is also the flexibility of its mounting options, specifically outdoors. From their literature: *"The Avenue Link is an all-outdoor small cell backhaul solution that combines a high capacity packet microwave system, flat-mini antenna and system cover in a small, zoning-optimized form factor."*

Figure 22 - Mounting options illustration from Dragonwave

[14] For more detailed information on their products, see http://www.dragonwaveinc.com/products/microcellular-platforms/avenue-link

To conclude this section, it is worth reiterating a few of the points made with respect to equipment and the role that pole attachments play in the decision on where to install wireless networking equipment:

1. Pole attachments are one of the commonly-accepted and encouraged methods for installing wireless networking equipment.
2. Small cells, Wi-Fi equipment, DAS antennas, and M2M sensors are the most common types of wireless networking equipment which can be attached to poles
3. The decision on whether or not to use a pole is dependent on a number of factors, including access to a power source, suitability from a coverage perspective, and business considerations

5. Commentary on Jackson Report

As part of the pre-filed evidence put forward by THESL, Charles Jackson, an Electrical Engineer, was asked to prepare an expert report which explored the coverage challenges wireless network operators face, the importance of the technologies they use in their networks to meet these challenges, as well as explore the necessity of utility poles for use as attachment points for equipment. The Jackson Report, as well as this report, were prepared independently, based on independent research and observations. The intention of both reports is to discuss the specific facts associated with wireless network technologies and deployments, rather than examine specific policies associated with pole attachment.

In this section, we will comment on select aspects of the Jackson Report. As an introduction, Chapter 3 of the Jackson Report, which is found on pages 2-23, serves as a good source of information on the current state of wireless networks. The author expands on certain aspects of wireless networking that were not explored in as great a depth in this report, and illustrates in a neutral fashion the way wireless networks operate. There are no specific issues to point out from that part of the report, and we agree with the statements he makes, as they are factual in nature.

On balance, it is our view that Charles Jackson presented a factual and accurate portrayal of the state of the industry, while offering some opinions that we feel may have gone beyond the scope of technical *needs*. We will now explore these variances.

5.1 *Necessity* of pole attachment vs. *ability* to use pole attachments

In the introduction and overview section of the Jackson Report (page 1), it is stated that one of the areas to be explored was:

> *Is access to utility poles necessary in order to facilitate the deployment of small cell and distributed antenna system networks in urban areas and, if so, to what extent?*

In the opinion of Nordicity, the phrasing of that particular question tends to lead to a particular conclusion with respect to *necessity* of pole attachments. As explored in sections above, it is our belief that the use of pole attachments is an *option* open to network planners / designers. It is one of numerous options. If you were to ask a network planner if they *could* deploy a wireless network without access to utility poles, the factual answer would likely be 'yes'. Much the same as if you asked that same network planner if they *could* deploy a wireless network without access to exterior building walls, the factual answer would again likely be 'yes'. However, in both situations, that network planner would *prefer* the option of having both utility poles and exterior building walls at their disposal when creating a network design.

In the Jackson report, it is evident from the presented data that the overall conclusion would likely be the same. Namely that having the *option* of pole attachments open to network planners is one of the tools in their arsenal for dealing with coverage challenges. Planning and deploying a wireless network, which involves making many decisions on where to site equipment, is a complex process. Having the most number of siting options at a planners' disposal will lead to the most efficient and effective network deployments.

5.2 Examination of Wireless Capacity Growth and Pole Access

In Chapter 7 of the Jackson Report (starting on page 29), the author explores this question of necessity and simply states that pole access is not a necessity, but concedes that there are some situations where it may be the only option, citing long stretches of roads with no other facilities available as an example. As previously discussed, it is our view that there should not be a need to answer that question in an absolute sense, as it may lead readers to a false assumption regarding the *utility* of having access to such structures.

Further in the same chapter, the author presented Table 1 (copied below) to be used to examine the issue of wireless capacity growth and the implications on having pole access. The table was appears to be designed to illustrate whether the need for pole access increases or decreases when choosing different methods of expanding capacity in a wireless network.

Figure 23 - Table 1 from the Jackson Report (page 30)

Table 1. Wireless Capacity Growth and Pole Access

Method of Expanding Capacity	Implications for Utility Pole Access
Cell Splitting with Macrocells	Reduces need for pole access
Additional Spectrum	Reduces need for pole access
Improved Technology	Reduces need for pole access
Indoor Small Cells	Reduces need for pole access
Indoor DAS	Reduces need for pole access
Outdoor Small Cells	Benefits from pole access
Outdoor DAS	Benefits significantly from pole access; benefits more than small cells.
Demand Management (pricing or usage caps)	Reduces need for pole access
Wi-Fi Offloading (Indoors)	Reduces need for pole access
Wi-Fi Offloading (Outdoors)	Benefits from pole access

While the content of this table itself is not a point of debate, it may again lead readers to false assumptions. In Nordicity's view, there are other considerations that may impact the suggested applicability of this table. As such, for the purposes of comparison and further exploration, we will re-state this table with an additional column for 'additional considerations' to describe some issues with the implications as listed.

Figure 24 - Expansion of Jackson Report Table 1

Method of Expanding Capacity	Implications for Utility Pole Access	Additional Considerations
Cell Splitting with Macrocells	Reduces need for pole access	Macrocell not as effective for improving urban capacity; pose siting challenges as well
Additional Spectrum	Reduces need for pole access	Spectrum is a finite resource, but even with additional spectrum, equipment needs to be deployed, which needs siting
Improved Technology	Reduces need for pole access	Neutral, it is not clear on what basis this would definitively reduce need to pole access. This depends on the specific technology
Indoor Small Cells	Reduces need for pole access	Indoor deployments suitable for certain situations, not all
Indoor DAS	Reduces need for pole access	Indoor deployments suitable for certain situations, not all
Outdoor Small Cells	Benefits from pole access	Pole access is one option open to network engineers
Outdoor DAS	Benefits from pole access	Pole access is one option open to network engineers
Demand Management (pricing or usage caps)	Reduces need for pole access	Policy Impacts of demand management could make this prohibitive (Gov't intervention)
Wi-Fi Offloading (Indoors)	Reduces need for pole access	Indoor deployments suitable for certain situations, not all
Wi-Fi Offloading (Outdoors)	Benefits from pole access	Pole access is one option open to network engineers

The intention of highlighting the additional considerations is to draw attention to the fact that for many of the methods of expanding capacity, the implications are not always black and white. Each method of expanding capacity carries its own considerations. Taking the example of cell splitting with macrocells, while this would reduce the need for pole access, this may not be the most desirable course of action for a network operator. In fact, throughout the Jackson Report, the author highlights numerous times the importance and growing role of deploying small cells rather than macro cells.

The net takeaway is that pole access continues to be an important option for network operators when designing and deploying their networks. The more fundamental questions are those of the policy concerns, and the economic investigation being examined in other reports and evidence as part of this proceeding.

5.3 Examination of Future Requirements

The Jackson Report does a good job of exploring the current state of wireless networks, and particularly, the role of small cells in mobile wireless network deployments. However, one area which is not explored in much detail are some of the other technologies and applications that may lead to an increased demand for utility pole access. To specifically address that shortcoming, this report has explored the notion of M2M communications and the role of sensors in urban centres going forward. While it is not possible to quantify in absolute terms the impacts to pole access demands, the trends do point to an increase in the need to find suitable locations for attaching wireless equipment of various types in the coming years.

One of the principal arguments against the use of pole access by the author was the question of access to power sources and backhaul connectivity (the ability to link directly via wires to a core network). As new technologies and techniques are developed which reduce the need for these things, it seems feasible that demand for pole access my increase, due to their ubiquity, and the ability to negotiate with one single entity for wide-spread deployments rather than deal with many different building owners for the case of building attachments.

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6. Conclusions

To conclude this report, we will circle back to the stated technical issues that were presented at the outset and accepted by the OEB Panel for inclusion in the proceeding. The combination of this report, as well as the expert report prepared and tabled by THESL, is intended to provide the materials required to ensure that these issues can be dealt with as needed.

6.1 Current and likely future state of modern wireless networks

Both this report and the Jackson Report have investigated and discussed this aspect, and have come to similar conclusions with respect to how modern wireless networks are planned, deployed, and used. There should be little doubt as to their current, and growing importance, as both reports stress this as a key driver in the communications space.

In addition, this report in particular has put additional focus on examining additional uses for pole access in the context of wireless networking developments in the future that are useful to consider in the context of this proceeding.

6.2 Network elements for which pole access is an option

Once again, both the Jackson Report and this one have explored the various pieces of network equipment which could make use of pole attachments, including examining some of the future technologies that might be used for M2M communications in the future. In virtually all cases, the equipment being examined served the purpose of functioning as a transmitting / receiving device for wireless traffic, including both voice and data. The services that they are being used for are as varied as the users themselves. There are almost no limits to the applications that can make use of wireless networks.

With respect to alternatives to pole access, both reports discuss the point that equipment could be attached not only to utility poles, but also to building walls, inside buildings themselves, on building roofs, or even make use of towers specifically built for this purpose. These options exist today, and have been the fundamental siting options for many years for wireless network operators.

In the context of technological alternatives to using equipment that is mounted on utility poles, the commentary focused simply on the fact that network operators could choose to deploy macro-cell equipment rather than small cell equipment, which could be considered a technical alternative. However, as discussed, this option can also be considered an alternative siting option. Regardless of which siting alternative a network operator chooses to use, the technology will always consist of antennas for transmission and reception of data.

6.3 Expectation that pole access needs will change in the future

Through empirical investigation of the data currently available, there is nothing to suggest that the need for pole access (or more specifically the option of pole access), will change in the future. As new services and applications are introduced, it is likely that additional, and increasingly smaller equipment will be made available which will make use of pole attachments.

Additionally, over the past number of years, there have been growing demands by municipalities, and the public at large, to reduce the amount of new cell towers and telecommunications equipment being installed in public spaces. This includes the erection of large towers, as well as new utility poles and so-called 'street furniture' (street-level cabinets used to house telecommunications equipment). Given that new poles are unlikely to be deployed, but siting options for equipment will still need to be found, it is Nordicity's view that the role of pole access would at worst remain the same, but is actually more likely to increase over time.