SEPTEMBER 2016

Bridging the Gap

21st Century Wireless Telecommunications Handbook

Joint Venture SILICON VALLEY

Acknowledgments

This report was prepared by David Witkowski, Executive Director, Wireless Communications Initiative at Joint Venture Silicon Valley. Jill Jennings created the report's layout and design; Duffy Jennings served as copy editor.

Joint Venture would like to thank the following people for their contributions and support of this project:

- William J. McShane II, Connected City Experience, *Philips Lighting*
- Joe Madden, *Mobile Experts LLC*
- Randall Schwabacher, *AT&T*
- Omar Masry AICP, *City & County of San Francisco*
- Chetan Sharma Consulting

JOINT VENTURE SILICON VALLEY

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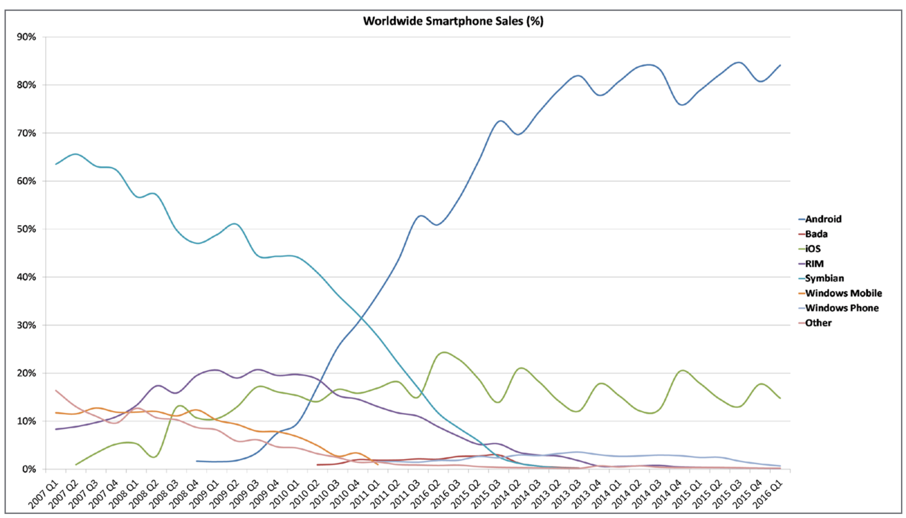
Introduction

Wireless technologies offer an exciting opportunity to connect people, solve problems in our cities, and make our lives better. This briefing was written primarily for municipal employees, public officials, and civic leaders to help guide their understanding of these technologies. This document will cover much ground. We'll look at what's driving the need for wireless data, the societal value of wireless data networks, the technologies that are being deployed to build those networks, and the regulatory environment for wireless facilities that govern how carriers and local governments must interact. We'll close with an overview of some new technologies that will likely be deployed in years to come, and some forward-looking recommendations for both local governments and wireless carriers.

> “Just over a decade after the economy was rocked by the collapse of the Dot-Com Boom, Silicon Valley has reinvented itself as the center of the Mobile Economy and the Sharing Economy.”

Wireless networks have come a long way since the first portable cellular call was made on the streets of New York City in 1973. In 1997, at a wireless conference hosted by Stanford University, a telecom executive famously declared, “voice is the killer app” and for a time this was gospel truth – until the Blackberry with its mobile email and rudimentary mobile browser became the must-have tool for businesspeople and then consumers. In 2010 sales of smartphones with Apple's iOS or Google's Android OS exploded, and the Blackberry went from a must-have gadget to e-waste in less than a year. Data was in fact “the killer app” as consumers switched their communication method from voice to texting and rich media.

Figure 1: Smartphone Sales by Year



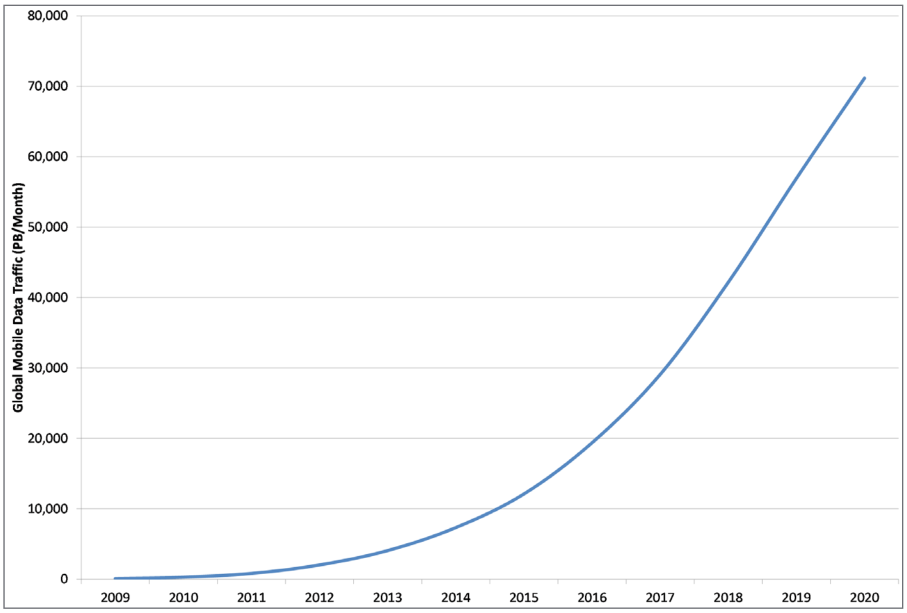
Source: Wikipedia, Gartner, IDC, Kantar Worldpanel

Just over a decade after the economy was rocked by the collapse of the Dot-Com Boom, Silicon Valley has reinvented itself as the center of the Mobile Economy and the Sharing Economy. Every company from the “Four Horsemen” (Google, Apple, Amazon, and Facebook) down to the smallest seed-funded startup has built its strategy around smartphone apps, cloud computing, and mobile networks – creating enormous demand for fast ubiquitous wireless coverage. A running joke in venture capital during 2016 is that an investment pitch deck must contain the phrase "Our vision is to be the Uber of…" to be fundable, and given the number of startups which are providing cloud-connected smartphone apps this may be somewhat true. Sharing Economy companies like Uber rely on wireless networks to request rides, locate passengers, provide safety by confirming identities, track vehicle movement for insurance purposes, and for completing payment and driver/passenger reviews in real time. Without a reliable and robust wireless network, Uber and hundreds of other new Mobile Economy companies could not exist.

"The wireless networks of the 21st century's first decade were designed to carry voice and small amounts of data, not to provide broadband data at speeds that rival or exceed wired broadband rates."

Mobile network operators, faced with skyrocketing demand that presented both an enormous opportunity and a seemingly impossible technical challenge, began shifting their deployment strategies away from voice telephony to mobile data for smartphones. Network operators have attempted to meet both consumer demands and regulatory requirements in a rapidly changing technology and economic landscape. The wireless networks of the 21st century's first decade were designed to carry voice and small amounts of data, not to provide broadband data at speeds that rival or exceed wired broadband rates. Mobile is a competitive business, and subscribers unhappy with their carrier's network performance can easily switch their phone number and service to another provider – the industry term for this is ***churn***. Carriers are so desperate to win customers that they'll offer hundreds of dollars to cover early termination fees and free phones worth hundreds of dollars – just to get subscribers to sign a 12 month contract.

Figure 2: Global Mobile Data Usage (per month)



Source: Mobile Experts LLC

To build a wireless network, spectrum must first be leased in a highly competitive auction conducted by the ***Federal Communications Commission*** – and this cost is not trivial. Wireless spectrum purchased during the spectrum auction known as "AWS-3" cost the bid winners over $44 billion, paid up front to the U.S. Government, and that was a relatively small auction – just one of many over the past three decades. (FCC AWS-3 Auction Results, 2015) Having paid for spectrum, the carriers then have to invest in wireless facility siting studies, pre-application meetings, permit applications, and engineering designs/redesigns. The equipment, personnel, and tools to install wireless networks are all funded up front. It takes years of monthly subscriber revenue before the carriers can realize a profit on these capital and operational expenses.

> "Fast and ubiquitous wireless networks are critical resources for our country's citizens."

Every time a call is dropped or a data connection is too slow, the wireless carrier risks losing a customer to churn. If an area often experiences dropped calls or slow data, a carrier will want to fix that problem – and that means upgraded equipment or new sites, which must be permitted by local governments. And that interaction hasn't always been positive.

Given the urgency placed on carriers to enhance networks, reduce churn, and meet users' demand for faster data it was probably inevitable that conflicts between carriers, operators, and local governments would arise. Carriers and operators feel that some local governments have treated applications for wireless facilities with either disdain or outright hostility, and that application processes are often unclear or arbitrary, and subject to repeated demands for eleventh-hour revisions. Local governments feel that some carriers and utilities have been dishonest in their applications, built systems that don't match the application's plans and rendered drawings, or failed to heed requests for integration with local design and architecture standards. Each side has their horror stories, and certainly each side has made mistakes. Our shared goal should be to move beyond those mistakes and go forward together in partnership between industry and local governments, to create world-class wireless networks that will support current needs and pave the way for future innovation. Fast and ubiquitous wireless networks are critical resources for our country's citizens, and failing to provide them is no different than failing to provide clean drinking water, natural gas, sewage service, or electricity. Yet we must also respect the need for minimalist, quiet, and aesthetically-pleasing infrastructure.

Factors Driving Change

User Demand for Mobile Data

By any measure, the demand for mobile data is enormous and not likely to slow down. Ericsson's 2016 Mobility Report estimates the consumption of data on mobile devices (smartphones, tablets, and mobile-enabled PCs) in North America was 1.3 Exabytes (1 Exabyte equals 1 billion Gigabytes) per month in 2015, and forecasts this will increase to 9.1 EB per month by 2021. Smartphones will drive the majority of that usage, increasing by 7x today's consumption. In 2015, the average smartphone in North America consumed 3.7 GB of data per month, and this will increase to 22 GB per month by 2021. (Ericsson AB, 2016) These usage rates are driven heavily by the Mobile Economy – a fundamental shift in user behavior in communication and commerce from PCs connected by wired internet to smartphones and tablets connected by mobile networks. In 2014 the Mobile Economy ecosystem contributed 3.5% of the economy in North America, at a value of $670 billion. This is projected to increase to $750 billion by 2020. (GSM Association, 2015)

> "In 2014 the Mobile Economy ecosystem contributed 3.5% of the economy in North America, at a value of $670 billion. This is projected to increase to $750 billion by 2020."

Figure 3: Economic contribution of mobile ecosystem to North American economy

Source: GSMA Intelligence

Users Want More for Less

While the number of users and the amount of mobile data they consume has gone up, market forces have driven down the average revenue per user. According to the Cellular Telephone Industry Association's 2015 Annual Survey, in 1993 the average revenue per user was $76.55, but in 2015 it was only $44.65. (CTIA, 2015) Free-market competition between carriers has been very successful in making wireless networks more affordable for more citizens, but it places enormous downward revenue pressure on the carriers.

Spectrum Scarcity

Spectrum is the term for the range of electromagnetic frequencies which are used to provide wireless services. Spectrum is like land – there's only so much of it. Every bit and byte of information we consume over a mobile network requires a certain amount of spectrum to make the connection. As of 2016 the amount of spectrum allocated to LTE use for wireless broadband data in the USA is over 2 GHz, which is barely enough to support our current mobile data usage. Like constructing a high-rise building to make efficient use of land, we can make our use of spectrum more efficient – but this approach has limits. One approach to improving spectrum efficiency is densification – reusing the spectrum from large macro towers that cover many square miles in systems that cover a few city blocks, the inside of a building, or even a single room. Known collectively as ***Heterogeneous Networks*** or ***HetNets*** these don't replace the large macro towers, but are supplemental to them – focusing scarce spectrum resources into areas where people tend to use the most data.

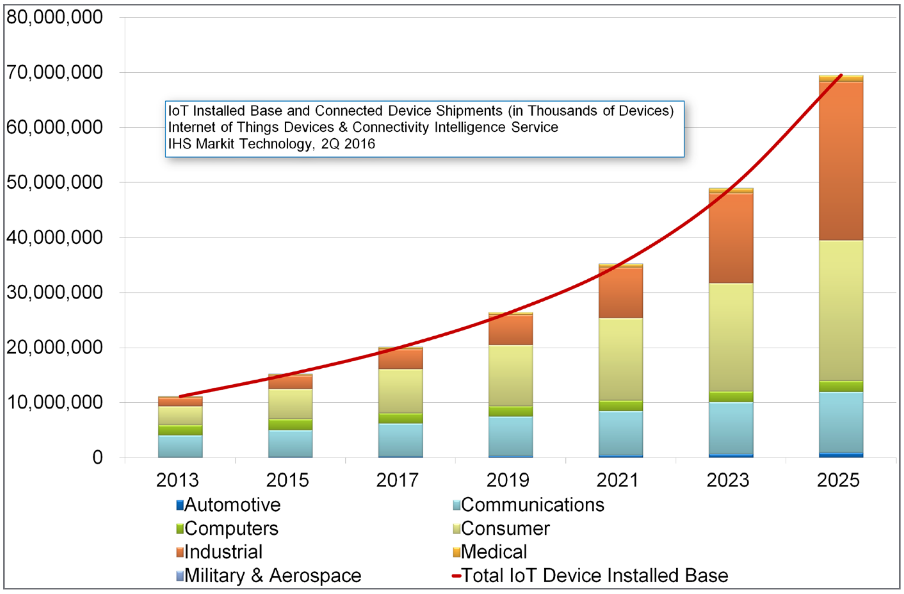
"One approach to improving spectrum efficiency is densification – reusing the spectrum from large macro towers that cover many square miles in systems that cover a few city blocks, the inside of a building, or even a single room."

There are two types of spectrum; licensed and unlicensed. Licensed spectrum is leased by regulatory authorities (such as the ***FCC***) to users, who then use the spectrum for various purposes. In most cases, the commercial lease holders of licensed spectrum must pay the government for an exclusive right to use that spectrum, the spectrum must be used to provide a "public good" such as wireless data networks, and the lease holders have legal standing to file a complaint against anyone who interferes with those systems. Unlicensed spectrum is the other type of spectrum – it's provided at no charge to the general public for use in consumer devices and conveniences such as garage door openers, cordless phones, and Wi-Fi networks in homes and businesses. The general public doesn't need a license to use this spectrum, but they also have no standing to pursue claims or file complaints about interference.

Smart Cities and the Internet of Things

Along with the rise in mobile subscribers and data usage, machines and autonomous devices are increasingly connected to the network. This so-called ***Internet of Things*** or "***IoT***" is predicted by the Ericsson Mobility Report to reach 15.7 billion devices in 2021. While not a firm definition, IoT typically refers to connected cars, sensors (including cameras), displays and actuators, utility metering and control, industrial systems, and consumer electronics. Systems that use IoT technology often form the basis of municipal Smart City systems for transportation, resource management, public safety, and other civic applications. IHS Markit Technology forecasts the installed base will grow to 69.5 billion units in 2025 and device shipments will grow to 18.1 billion units in 2025. (IHS Markit, 2016)

Figure 4: IoT Devices - Installed Base & Device Shipments



Source: IHS Markit Technology, Internet of Things Devices & Connectivity Intelligence Service, 2Q 2016

> “In the past, technologies like 4G have taken several years to reach dominance – in fact, most analyst forecasts show that 4G subscriptions won’t exceed combined 2G + 3G subscriptions until 2021.”

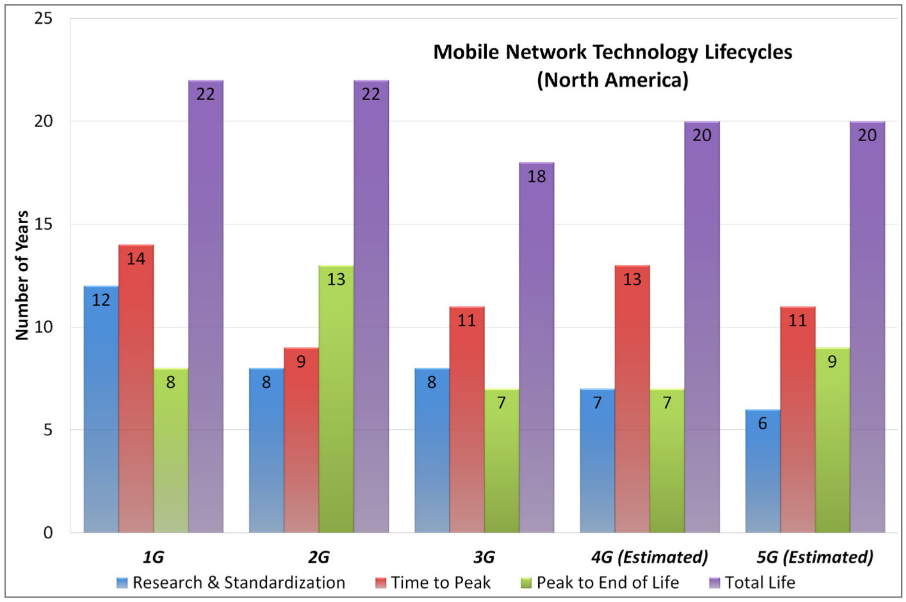
2G / 3G / 4G / 5G

In the early days of digital cellular telephony, the definition of a wireless system’s “generation” was not standard and was used primarily as a marketing device. As the first analog cellular systems gave way to new digital cellular, the newcomer was called ***Second Generation*** or ***2G***. The UN’s ***International Telecommunications Union*** (ITU) began seeking international agreement on, and publishing recommendations for, standardized definitions that next-generation systems would have to meet. The ***Third Generation*** or ***3G*** family of standards was known as IMT-2000. (International Telecommunications Union, 2011) The ITU defined recommendations for the 4G family standards as IMT-Advanced which was standardized as “Long Term Evolution” or LTE, and the ***5G*** family of standards will be known as IMT-2020. (ITU, 2016)

The Long Road to 5G

Much has been written about 5G, the next evolution of mobile broadband. Targeted by the ITU for final publication in 2020, 5G will contain many features that support high-speed data, increased spectrum efficiency, and support the Internet of Things. 5G deployments will be driven by carriers and network operators, and will require significant up-front investments from them. Meanwhile LTE continues to evolve, with new features added every year. In the past, technologies like 4G have taken several years to reach dominance – in fact, most analyst forecasts show that 4G subscriptions won’t exceed combined 2G + 3G subscriptions until 2021. By 2021 there will be about 150 million 5G subscriptions – a small number relative to the massive number of 4G subscriptions. (Ericsson AB, 2016)

Figure 5: Mobile Technology Lifecycles (North America)



Source: Chetan Sharma Consulting

> “Consumers are increasingly giving up wired telephones and even wired broadband in favor of mobile networks. This is especially true of younger people but also in economically disadvantaged communities.”

Societal Value of Wireless Broadband

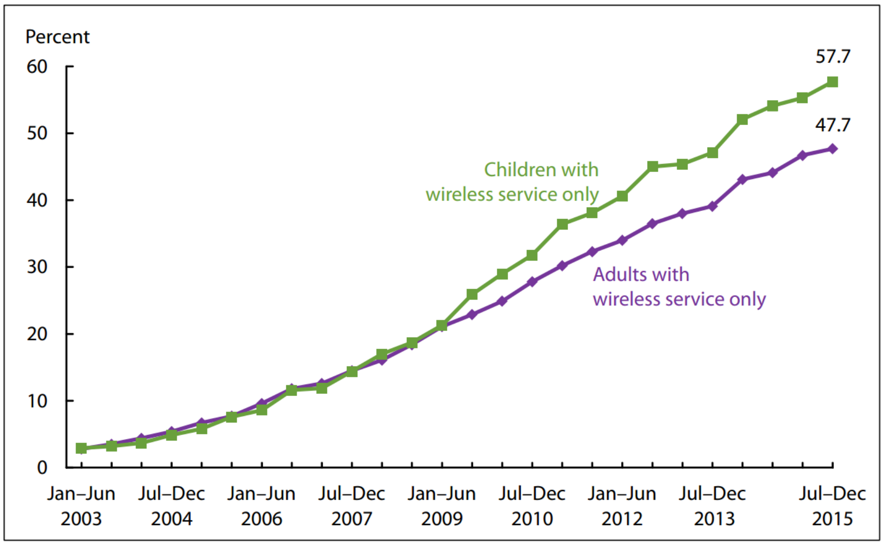
Wireless Voice and Broadband are Not Luxuries

Consumers are increasingly giving up wired telephones and even wired broadband in favor of mobile networks. This is especially true of younger people but also in economically disadvantaged communities. The reason is simple – given a limited household budget, the convenience of a mobile device both at home and away from home outweighs the inconvenience of lower data rates and possible dropped calls.

Increased Demand for Wireless Connectivity

Twice a year the U.S. Department of Health and Human Services publishes the Wireless Substitution Report via the Centers for Disease Control, based on data from the National Health Interview Survey. These reports have consistently shown an increase in the rate at which people are giving up wired phones for wireless. Estimated results from the May – December 2015 survey show that nearly one-half of all households nationally (48.3%) did not have a landline phone but did have at least one wireless phone. Looking nationwide approximately 47.7% of all adults lived in households with only wireless phones, and 57.7% of all children lived in households with only wireless phones. These numbers are notably higher for the western U.S. region (including California) where wireless-only rates exceed 51%. The results from other demographics are striking. Almost 3 in 4 adults (72.6%) under the age of 29 did not have wired phones. 68.8% of renters were wireless only, as were 78.8% of adults living with roommates. 60.5% of Hispanic families and 64.3% of families below the poverty line did not have wired phones. (Centers for Disease Control, 2016) This trend towards wireless-only connectivity is likely to continue for many years to come.

Figure 6 : Percentages of adults and children living in households with only wireless telephone service: United States, 2003-2015



Note: Adultes are aged 18 and over; children are under age 18.
Source: NCHS, National Health Interview Survey

> “Households with annual incomes below $25,000 are 29% likely to be accessing the internet via only mobile broadband.”

Wireless Broadband is a Primary Internet Access Tool

Giulia McHenry, Chief Economist, Office of Policy Analysis and Development for the U.S. Department of Commerce, published a blog article which showed that American households are rapidly shifting their broadband connectivity from wired (cable, DSL, etc.) to wireless. (McHenry, 2016) The article's source data comes from the U.S. Census Bureau's "Computer and Internet Use Supplement" to the Current Population Survey (CPS), which includes data collected for the NTIA in July 2015 from nearly 53,000 U.S. households. The results of this survey are striking – Households with annual incomes below $25,000 are 29% likely to be accessing the internet via only mobile broadband, and households between $25,000 and $49,999 annual income are 24% likely to be mobile-only. Survey data from The Field Poll in 2016 found that 14% of California residents connect to the internet only through a smartphone. For households earning less than $22,000 per year, the rate is 25%. (CETF, 2016)

Broadband Access Reduces Unemployment

In March 2016, the White House's Council of Economic Advisers issued a briefing which showed that access to the internet reduced the duration of unemployment periods. In households with access, the likelihood someone would be employed again within 12 months was almost 50%. In households without access, the rate was only just above 30%. (White House Council of Economic Advisors, 2016) This should be no surprise – job posting and job application are increasingly done online and via email. Lower income earners are often employed in temporary positions – and with increasingly more lower-income workers employed in ***Sharing Economy*** and ***Gig Economy*** jobs the timeliness of their response to openings is critical. A slow mobile data connection can prevent a ride-share service driver from claiming a passenger. A missed email or phone call means a temporary worker doesn't learn about an opportunity to get work, and the job goes to someone else. Given what we know from McHenry's NTIA article, it becomes clear that failure to provide a robust mobile broadband network has a direct and asymmetrical impact on our nation's most vulnerable citizens.

> "Research published in 2016 shows that over 25% of residents in major U.S. cities such as Los Angeles and New York don't have readily available access to the internet."

Unconnected Cities

It's easy to think the problem of unconnected citizens only exists in third world countries or remote towns in the mountains, but this is incorrect. Research published in 2016 shows that over 25% of residents in major U.S. cities such as Los Angeles and New York don't have readily available access to the internet. (Maravedis & Wi-Fi 360, 2016)

Mobile Network Densification

Densification and Heterogeneous Networks

Densification is the term for adding equipment to augment existing mobile networks and provide additional capacity in areas of high usage. Densification technologies include Distributed Antenna Systems (DAS) and Small Cells. Because these are different from large macro towers but operate in cooperation with them, a densified network is sometimes called a ***Heterogeneous Network*** or ***HetNet***.

Figure 7: Small Cell and DAS Sites Add Capacity to Existing Networks

Source: Joint Venture Silicon Valley

"Usage of mobile data occurs where humans congregate, and 80% of mobile data is consumed while the user is relatively fixed in location."

Why are HetNets Important?

Usage of mobile data occurs where humans congregate, and 80% of mobile data is consumed while the user is relatively fixed in location. Draw a box on a map, highlight the areas where 90% of the data is used, and 95% of the map will be dark – we don't typically consume large amounts of data while standing in the middle of an empty field. We use data in our homes, workplaces, vehicles, restaurants, shopping malls, and sports venues. Of course, when people congregate in areas and use data all at once the amount of data available is averaged over the users – resulting in slow connections and poor performance. HetNet technologies allow network designers to concentrate resources and serve high demand areas with dense populations. Of course, usage in any given area can vary by day of the week, time of day, or the season. A beachside tourist area needs lots of capacity on weekends during summer, a bit less during summer weekdays, and almost no capacity during the middle of a week in the dead of winter.

HetNet Ordinances and Codes

Some ordinances written during the early days of cellular telephony don't differentiate between the smallest wireless facility attached to a utility pole and a 70-foot-tall macro tower – and this is a mistake. HetNet systems are very different than large macro tower systems, and should be covered under separate ordinances and codes that account for those differences.

Municipal ordinances and codes sometimes encourage ***co-location*** (the term for wireless facilities from multiple network operators that are attached to the same physical structure) by requiring minimum separation distances between wireless systems. In the early days of cellular telephony this separation might have made sense, but HetNets can be located closer together without creating safety, interference, or performance issues. Sometimes these outdated separation ordinances force network operators to locate HetNet facilities in undesirable locations, which is neither ideal for optimizing network performance nor a good investment for the network operator. Municipal governments should revise separation ordinances to allow closer placement of HetNet facilities to adjacent sites.

"The definition of what constitutes a Small Cell is not yet standardized... One common definition is that a Small Cell is a self-contained wireless access node."

Distributed Antenna Systems

Distributed Antenna Systems or ***DAS*** systems are created when multiple antenna nodes are attached via coax cable or fiber to centralized radio equipment – hence the term "distributed." Connection of the radio equipment to the core network is typically done via fiber optics. DAS systems are most often used indoors to provide robust coverage inside convention centers, large buildings, and shopping centers. There are also outdoor DAS (o-DAS) networks – typically along driving routes where the terrain is difficult to cover with macro towers, and in parks and sports stadiums. The benefit of DAS is that the antennas are typically small and simple to install. The downside of DAS is that the signal levels from each antenna need to be balanced and adjusted to ensure uniform coverage and avoid gaps.

Small Cells

The definition of what constitutes a ***Small Cell*** is not yet standardized. This creates a challenge for municipal governments when they try to create telecom ordinances and do planning to manage applications for wireless facilities that fall under federal and state laws. One common definition is that a Small Cell is a self-contained wireless access node. There are several types of Small Cell technologies:

- Femtocells that cover a single room
- Picocells that cover several rooms
- Microcells that cover buildings and large areas
- Metrocells which are typically used in outdoor environments to cover community areas parks or residences over a few square blocks

Small Cells are used in HetNets to provide densification so another common definition of a Small Cell is based on the signal coverage area, described by the Small Cell Forum as "typically [having] a range from 10 meters to several hundred meters". (Small Cell Forum, 2016)

The benefit of Small Cells is that each acts as an independent node of a network, under control of the carrier's monitoring and control system. The downside is that fiber and power must be run to each node, and because the equipment comprises both the radio and the antenna, the total volume needed to house each node is larger than DAS. The rate of deployment for Small Cells by carriers will grow exponentially over the next five years. Analysis by Mobile Experts LLC forecasts that carrier-owned Small Cell installs will reach nearly 1.5 million units per year worldwide by 2021. (Mobile Experts LLC, 2016)

"HetNets are intended to augment existing networks, not replace them...Large towers provide connection continuity as users move from one HetNet node to another."

Will HetNets replace large macro towers?

HetNets are intended to augment existing networks, not replace them. Although most typical mobile usage occurs in a small area, occasional use can occur anywhere and failure to provide wide area coverage creates a public safety issue. Large towers provide connection continuity as users move from one HetNet node to another, ensuring the smooth transfer of the voice or data connection between nodes. We still need the macro tower network to provide this wide area coverage, and the rise of Small Cells and DAS should not be seen as an opportunity to tear down large macro towers. Large towers are also used for other purposes such as public safety (police, fire, and medical) two-way radio, private microwave networks, and wireless internet service providers who provide a competitive alternative to wired broadband.

Definition of Small Cells by RF Power

Some industry definitions of Small Cells are based on Radio Frequency (RF) power output levels, which are smaller than those in large macro towers. Other definitions are based on the Small Cell's Effective Radiated Power (ERP) or Effective Isotropic Radiated Power (EIRP), which are calculated after adding in antenna gain and subtracting system losses. The gain or loss of RF power in a system is rated in decibels – a logarithmic measurement of ratio, abbreviated "dB". (This should not be confused with "Audio Decibels" a term used to measure the loudness of sounds.) Output power may be given in either Watts, or in units of dBm.

Calculations of RF power, system losses, and antenna gain are complex. If you don't have an electrical engineer with a wireless background on staff, it's strongly recommend you hire or retain one as a consultant or contractor.

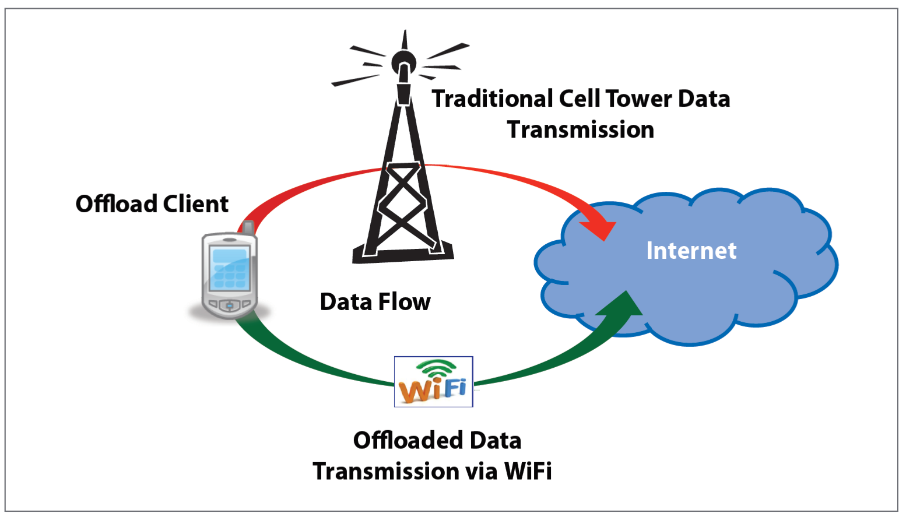
Wireless Network Offload

Even with HetNet technology for densification, the availability of RF spectrum is a key component in how much information can be passed over a wireless network. In 2008, the Cellular Telephone Industry Association (CTIA) told the Federal Communications Commission that mobile carriers would eventually need an additional 800 MHz of RF spectrum (on top of the aforementioned 2 GHz already in use by the industry) to keep up with projected demand. (CTIA Filing to FCC, 2009) Unfortunately, this amount of spectrum is simply not available, and the costs to acquire it would be very high. FCC is trying to shift some of the old television spectrum to the wireless carriers, and the estimated costs (as of July 2016) for reclaiming only 100 MHz of this TV spectrum is $86 billion. (FCC 600 MHz Auction, 2016)

"Even with HetNet technology for densification, the availability of RF spectrum is a key component in how much information can be passed over a wireless network."

To deal with rising user demand and limited spectrum carriers have begun to look at other ways to increase capacity, using a technique called ***Offload***. Offloading refers to the process where the mobile network instructs the user's device to connect via equipment running in unlicensed spectrum under the carrier's control. So for example, if a subscriber wants to watch a streaming video the network would serve that request by determining if an offload site is within range, and if so divert the user's data connection to obtain the data via the offload network, leaving the carrier's network free to handle other traffic.

Figure 8: Mobile Network Offload Using Wi-Fi



Source: President's Council of Advisors on Science and Technology, June 2012

Wi-Fi

Most of us know ***Wi-Fi*** as the technology we use in our homes and offices to connect devices wirelessly to a local area network. Wi-Fi is based on the IEEE 802.11 family of standards, and has evolved many times over since its first release in the early 1990s. At the technology level modern Wi-Fi shares many traits with mobile broadband standards such as LTE – the differences between them are that Wi-Fi was originally designed as a consumer technology to easily create local private networks, whereas LTE was designed as a network operator technology operating under centralized control to create wide-area commercial networks.

Wi-Fi is great for attachment of nearby semi-stationary devices, but unlike LTE it does not work well when the device is moving quickly. This is because the Wi-Fi standard does not provide a mechanism to shift a device's connection to another access point when the signal becomes weak, and the range of a Wi-Fi access point is in practice no more than 250 meters. This creates a condition known as "fail before fix" – a device will remain attached to a Wi-Fi access point until the signal is completely gone and only then will it begin looking for a better option. One can imagine how this would play out while driving down a street or highway – by the time a device attached itself to an access point, it would be out of range. In contrast, cellular telephony and data networks provide devices with a list of nearby sites, and when the signal from a nearby site grows strong enough the device requests a ***handoff*** to a nearby site.

"Wi-Fi was originally designed as a consumer technology to easily create local private networks, whereas LTE was designed as a network operator technology operating under centralized control."

Historically one drawback of Wi-Fi has been that it didn't allow ***roaming*** – the ability to use the Wi-Fi networks of other operators when you're not in range of a network where you have an account. To use another network you have to connect manually, often with a password. Over time your smartphone's list of Wi-Fi networks grows, and that list has to be managed manually. This is changing as Wi-Fi network operators deploy a technology called "Hotspot 2.0" or "NGH 2.0" that allows your phone to automatically attach to any NGH 2.0 hotspot that has an agreement with your operator. Not many smartphones are capable of supporting NGH 2.0, but this will change as new phones are released.

Wi-Fi can be used as an offload technology under control of the carrier network, in a process called ***LTE - Wi-Fi Link Aggregation*** or ***LWA***. LWA Wi-Fi nodes are typically co-located with the carrier equipment, usually built into the Small Cell housing. While initially a popular idea, the challenges of managing two parallel networks has greatly reduced the likelihood that LWA will become dominant, and network operators have been shifting focus away from LWA towards other techniques.

LTE Unlicensed

Mobile operators are strongly considering deployment of ***LTE Unlicensed*** or ***LTE-U***, which is an offload technique that uses LTE signals in the unlicensed bands. LTE-U is attractive to network operators because it's purely LTE; there are no auction costs to the operator, and no license application process for using unlicensed spectrum. Handoff and roaming are easily done, as they're already part of the LTE standard. However because the spectrum is unlicensed the operators have no ownership rights, so if an LTE-U system experiences interference from another system the operators must work out their differences privately or resolve the problem through technical means.

The question of whether LTE-U can politely co-exist and share unlicensed spectrum with Wi-Fi is still being considered – after extensive debate between the Wi-Fi and LTE-U vendors a coexistence test plan is due to publish in September 2016, and some early test results have been published, but comprehensive results will not be available for some time.

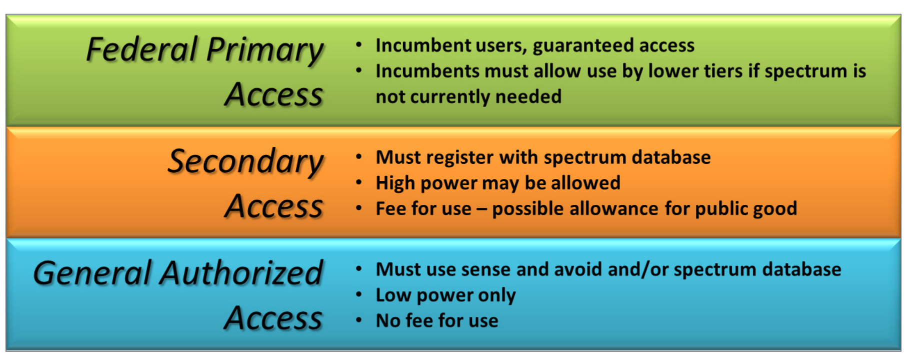
Another offload technique uses Wi-Fi connections under control of the carrier network, in a process called ***LTE - Wi-Fi Link Aggregation*** or ***LWA***. These Wi-Fi nodes are typically co-located with the carrier equipment, usually built into the Small Cell housing.

“Mobile operators are strongly considering deployment of LTE Unlicensed or LTE-U, which is an offload technique that uses LTE signals in the unlicensed bands.”

In April 2015, the FCC created the ***Citizens Broadband Radio Service*** or ***CBRS***, a 150 MHz allocation in the 3.5 GHz band intended for use by Small Cell equipment. Because the CBRS band overlaps with some existing satellite communication systems, the CBRS band defines three tiers of users: Incumbent Access (IA), Priority Access (PA), and General Access (GA). IA users are federal entities like the Department of Defense, arms of the military, etc. PA users will have to pay for preferential access to CBRS, and in return they'll receive protection from GA users. GA users will be able to use CBRS for free – very much like the current unlicensed bands – but GA will have to stop transmitting if a PA user claims priority to the frequencies. In CBRS, the priority system is managed by a central licensing database, and this licensing system is still under development.

To date, only IA and PA users have been authorized to use the band. In order to use CBRS spectrum, the user's equipment must first be able to determine if other users have priority, which means that another data network must be accessible. It remains to be seen if GA use of CBRS will ever become a reality. In the long run, it's expected that the CBRS band will be able to provide a large amount of RF bandwidth for carriers seeking to serve user demand, and that CBRS Small Cells will dominate by 2021. (Mobile Experts LLC, 2016)

Figure 9: Federal Government Tiering Structure for 3.5 GHz Small Cell Band



Source: Joint Venture Silicon Valley

Backhaul is Critical for Wireless Broadband

Every node in a wireless network, from the smallest femtocell to the largest mountain-top macro tower, requires a connection to the carrier's data network. For femtocells and picocells, this is typically done with Ethernet connection via an in-building network. For metrocells, microcells, and DAS deployments, fiber optic connections are used. If neither fiber nor Ethernet are available, wireless connections may be used. This connection of a wireless site facility to the operator's core network is called backhaul.

A common technology for backhaul is fiber optics. There are two kinds of fiber optic networks – ***lit fiber*** and ***dark fiber***. If a section of fiber optic and the associated network hardware is owned by a company that then sells capacity on that system to more than one user or network operator, the fiber is said to be "lit." If a section of fiber optic cabling is leased solely for one network operator, or is installed by a utility for later use by a customer, the fiber is said to be "dark." In almost all cases, mobile network operators want dark fiber because this gives them control and allows them to ensure the highest levels of service quality. If dark fiber is not available then it needs to be installed – either via aerial runs along poles, into existing conduit, or via new conduit. Underground construction is time consuming, expensive, and potentially disruptive to existing underground systems – so installing conduit for future use during other construction projects is increasingly popular.

> "Every node in a wireless network, from the smallest femtocell to the largest mountaintop macro tower, requires a connection to the carrier's data network."

The availability of dark fiber and conduit is a key enabler to making the transition to HetNets a reality. Network operators will typically take advantage of any dark fiber and conduit they can obtain. Conduit and fiber are relatively inexpensive to install when the work is done during other construction projects, and can be used for future municipal purposes such as business park build-outs, smart city networks, and providing broadband at home to citizens.

Wireless backhaul is an emerging technology that can be used where aerial runs or conduits are not available. These systems use extremely high frequency channels (in the 60 – 70 GHz range) to pass large amounts of data. Due to limitations in how RF signals behave at these frequencies, designing and deploying a wireless backhaul network requires a level of engineering sophistication beyond that of fiber optics, and as such in most cases it remains a more complex solution that's used only when fiber and conduit not available.

Wireless Telecom Legislation

Overview & Background

Since the early days of cellular telephony the federal government has sought to encourage deployment of a robust nationwide wireless network. The federal government, recognizing the economic and social benefits of that network, enacted laws that attempt to facilitate and encourage deployment. In some cases states such as California have encapsulated the federal laws and extended them. Some may argue that these laws are beneficial – others may disagree. A full treatment of these laws and their application to real-world situations is beyond our scope, but this handbook provides an overview of the most consequential ones.

> "The federal government, recognizing the economic and social benefits of that network, enacted laws that attempt to facilitate and encourage deployment."

Telecommunications Act of 1996

The Telecommunications Act of 1996 (the "1996 Act") was the federal government's first attempt to help create a foundation for the wireless communications revolution we're now experiencing. The 1996 Act contained provisions concerning the placement of towers and other facilities for use in providing personal wireless services. Section 704 of the 1996 Act governs federal, state, and local government oversight for placement and construction of "personal wireless service" facilities. (FCC, 1996)

"Personal wireless services" as defined in the 1996 Act included commercial mobile services, unlicensed wireless services, and common carrier wireless exchange access services.

"Commercial mobile services" are defined in Section 332 of the Communications Act and the FCC's rules, and include wireless telephone services regulated under Part 22 of the FCC's rules, SMR services regulated under Part 90 of the FCC's rules, and PCS regulated under Part 24 of the FCC's rules. (FCC, 1996)

The 1996 Act states that local governments may not take actions to discriminate against or outright prohibit (or have the effect of prohibiting) personal wireless service facilities, preempts any local government attempts to regulate on the environmental effects of RF emissions, and requires local governments to act "within a reasonable time" on requests to place, construct, or modify personal wireless service facilities.

Section 332 – The FCC "Shot Clocks"

The problem with the 1996 Act was that "reasonable time" was left to interpretation. A wireless carrier seeking to solve a critical coverage problem might consider approval within 30 days reasonable, while a local government greatly concerned with historical preservation or responding to a citizen opposition group's concerns about the health effects of wireless technology might consider an application process lasting 5 years or longer to be reasonable.

So in 2009 the FCC issued a Declaratory Ruling stating that 90 days is a presumptively reasonable timeframe for processing collocation applications ("collocation" defined as adding equipment to an existing wireless facility), and

150 days is reasonable for anything that is not a collocation application. These have become known as the "Shot Clocks" because, like in professional sports, they compel action within a certain period of time. It should be noted that the 90- or 150-day timeframes are based on calendar days, including weekends and holidays, from the date that an application is filed. The clock governing an application may be paused or "tolled" by mutual written consent of both the applicant and the local government, or if the local government notifies the applicant in writing (via a Notice of Incompleteness or "NOI") that the application is incomplete. Section 332 imposes several requirements on local government if issuing a Notice of Incompleteness:

- The NOI must specify the code provision, ordinance or publicly stated procedures that require the missing information to be submitted;
- The NOI cannot impose new application requirements;
- Supplemental NOIs issued against NOI responses must be based on the original NOI.

> "The clock governing an application may be paused or "tolled" by mutual written consent of both the applicant and the local government, or if the local government notifies the applicant in writing."

Section 6409(a) of the Spectrum Act 2012

The Middle Class Tax Relief and Job Creation Act of 2012 made provisions in Title VI that expedite the availability of spectrum for commercial mobile broadband. The provisions in Title VI – also known as the Public Safety and Spectrum Act (the "Spectrum Act") contained legislation known as Section 6409(a) that further clarifies how the local governments must respond to applications governed by the 1996 Act and the FCC's Shot Clocks. Section 6409(a) also adds a requirement to approve minor modifications on existing "eligible facilities" within 60 days; however this applies only to an "eligible facilities request." (Congressional Research Service, 2014)

Section 6409(a) defines an "eligible facilities request" as any request to modify an existing cell tower or base station that involves collocating new transmission equipment; removing transmission equipment; or replacing transmission equipment. These modifications could include changes that increase the width or girth, but do not "substantially change" the height of a wireless facility, i.e., a tower or monopole.

Section 6409(a) does several things in relation to the 1996 Act and the Shot Clocks. First, it says that the Shot Clock applies regardless of any local moratoria. Second, it says that the Shot Clock starts to run when an application is first submitted, not when it's deemed complete. The clock is tolled only after the local government notifies the applicant within a specified time that the application is incomplete and that the notice of incomplete application must "specify the code provision, ordinance, application instruction, or otherwise publically stated procedures that require the information to be submitted." Under Section 6409(a), a decision to deny a personal wireless service facility application must be done in writing and the denial must be supported by substantial evidence in a written record.

For many local governments, Section 6409(a) creates a key and critical issue because they have not created codes, ordinances, instructions, and procedures for managing modern wireless facility applications. This is especially true for DAS and Small Cell technology, which are fundamentally very different from applications for large macro towers that local governments have managed in the past. Smaller communities that have relied on wireless signals from adjacent towns or wireless facilities on private property will likely be faced with applications to install DAS and Small Cell facilities on utility poles or in the public right-of-way – and many are not ready to respond to these kinds of applications. Regardless of readiness, the Shot Clock will start running when these applications are submitted, and local governments should begin preparing now to respond to them by adopting ordinances and updating codes to cover the growing use of DAS and Small Cell facilities in the public right-of-way.

“This is especially true for DAS and Small Cell technology, which are fundamentally very different from applications for large macro towers that local governments have managed in the past.”

California AB 57

For California's local governments, there's an additional twist to the Section 6409(a) and Shot Clock story. In October 2015, the state passed a law that further limits the ability of local governments to apply discretion in approval of wireless service facilities. Following the "Deemed Approved" approach of California's Permit Streamlining Act, a wireless facility subject to Section 6409(a) that is an "eligible facility" and has not been justifiably denied is "deemed approved" if the applicable FCC Shot Clock timeframe runs out. (150 days for new installations, and 90 days for co-locations.) Unlike under the Permit Streamlining Act, AB 57 does not allow the Shot Clock to be paused due to delays in conducting a complex environmental review under the California Environmental Quality Act (CEQA). This means that local governments should be prepared for these applications well in advance, and be prepared to act on applications in a timely manner, or risk lawsuits for failing to respond under the law.

It's important to note that AB 57 has a few exception cases. It does not apply:

- to actions by the California Coastal Commission or other state review agencies such as the San Francisco Bay Conservation and Development Commission;
- to City/Town properties such as parks and city-managed campuses;
- or to facilities at fire stations.

Application Processes, Checklists, Codes and Ordinances

When developing codes, ordinances, instructions, and procedures for handling wireless facility applications, local governments should be very specific about what constitutes a "complete application" and be very clear about what must be contained in a complete application. These requirements should be backed up with ordinances, and supported by published instructions and procedures. Local governments should publish a wireless facility pre-application checklist, and publish a clear and comprehensive application process.

CPUC Rulemaking 14-05-001

In October 2015, the California's Public Utilities Commission issued a proposed decision on Rulemaking 14-05-001 for "Decision Regarding the Applicability of the Commission's Right-Of-Way Rules to Commercial Mobile Radio Service Carriers" which sets rules for placement of wireless facilities equipment on utility poles, cabling and interconnections in ducts and conduits, and attachments in the public right-of-way. The decision amends the CPUC's right-of-way rules to provide commercial mobile radio service (CMRS) carriers with nondiscriminatory access to public utility infrastructure, equal (with one exception) to the access afforded previously to CLEC and CATV providers. As of this writing, the decision has not been finalized. (CPUC 14-05-001, 2015)

> "When developing codes, ordinances, instructions, and procedures for handling wireless facility applications, local governments should be very specific about what constitutes a "complete application."

The likely outcome of this ruling (if published as proposed) will be additional requests to install Small Cell antennas on the tops of utility poles. Systems like this already exist, with equipment either on the pole or in a ground-level vault, and antennas mounted to the side or top of the pole. CPUC R-14-05-001 will provide a streamlined process for wireless carriers to work with pole owners. Done well, these installations can add value with minimal community impact. Done poorly, they can generate resident complaints and concerns about aesthetics.

Figure 10: Good and bad examples of HetNet deployments

Credit: Philips Connected City Experience

Credit: Omar Masry, AICP

> “HetNet technology provides the best opportunity for carriers to make the most efficient use of limited RF spectrum in the face of exponential growth in mobile data usage.”

Wireless Telecom Roadmap – What Does The Future Hold?

Increased Deployment of HetNets

For the reasons previously outlined in this handbook, local governments should prepare for applications to install DAS and Small Cell facilities, especially on utility poles in the public right-of-way. HetNet technology provides the best opportunity for carriers to make the most efficient use of limited RF spectrum in the face of exponential growth in mobile data usage, and Small Cell technology is a key component in deployment strategies for major carriers.

LTE in the Unlicensed Bands

Local governments, especially those that have deployed – or are considering deployment of – Wi-Fi networks in the 5 GHz band should closely monitor the trials and co-existence tests of LTE-Unlicensed. We don’t know yet how well Wi-Fi and LTE-U will behave in large-scale real-world deployments, and procedures for how to test for and mitigate interference are still under development.

Wi-Fi Carriers & Voice-over-Wi-Fi

"We expect that in parallel with deployment of LTE-Unlicensed, there will be a growth in the use of Wi-Fi networks as an alternative to traditional mobile carriers."

We expect that in parallel with deployment of LTE-Unlicensed, there will be a growth in the use of Wi-Fi networks as an alternative to traditional mobile carriers. We've seen a rise in Wi-Fi First business models where the subscriber's phone seeks out Wi-Fi as a preferred network for both voice and data, only falling back to cellular when necessary – and this will place pressure on Wi-Fi network providers to deploy faster networks with more capacity. Roaming agreements between Wi-Fi providers will allow users more flexibility to access networks in more places, and this may provide an opportunity to monetize Wi-Fi networks to offset capital and operating expenses. Wi-Fi First carriers charge subscriptions rates well below traditional carriers, so these phones offer a great opportunity to provide wireless telephone service to lower-income citizens who may not qualify for discounted telephone rates. Unfortunately, the Wi-Fi standard suffers from limitations which prevent it from achieving its full potential as a carrier-grade connection technology. Managing logins for large numbers of users is challenging, the ability to roam from one network to another without having to login again is largely non-existent, and users have to maintain and manage their own list of known networks. Wi-Fi lacks an authentication method, and without authentication it's fairly easy for a hacker to record user data by pretending to be a trusted Wi-Fi network. Unlike cellular data standards, Wi-Fi does not have a "handoff" mechanism, which means when a user moves from one Wi-Fi access point to another the connection is interupted for a brief period of time. Yet the popularity of Wi-Fi as a replacement for wired Ethernet has led to wide proliferation of systems, which tend to interfere with each other, leading to reduced performance.

Wi-Fi for IoT

Several cable companies are deploying Wi-Fi networks through line-attach equipment and public-facing hotspots on leased gateway equipment in homes and businesses. While not typically fast enough to support high-bandwidth usage for large numbers of users, these Wi-Fi networks are potentially good for handling Internet of Things traffic, which is typically less bandwidth intensive and more tolerant of network latency. Evolutions in the standards family that governs Wi-Fi have been released that make it more suitable for IoT applications.

Dedicated IoT Networks

Competing with Wi-Fi and mobile data networks for IoT are several proprietary standards, collectively known as Low Power Wide Area (LPWA) systems. Because they were designed specifically for IoT applications, they can be better in terms of power consumption, which is often a key design criterion for IoT systems. The downside is that in many locations the networks do not yet exist, so siting and permitting effort will be required. In most cases LPWA facilities are small, with equipment cabinets less than 12 cubic feet and antennas about 3 feet long, and thus have minimal aesthetic effect. Local governments should consider implementing streamlined review processes for LPWA equipment and sites.

FirstNet – LTE for Public Safety

> “FirstNet’s wireless facilities are dictated by the needs of public safety, not commercial carriers seeking to serve the public.”

The Spectrum Act of 2012 contained legislation and funding for what is now called ***FirstNet™*** – a nationwide LTE network dedicated for use by public safety and First Responders. As of this writing FirstNet has just completed its RFP process and decisions are expected in late 2016, after which the network must be built. While the federal government allocated over $7 billion in funding for FirstNet the final amount needed will be much higher, so the question of ongoing revenue and build-out funding remains to be answered. Once it reaches the deployment phase, FirstNet will provide a unique challenge to local governments because the locations of FirstNet’s wireless facilities are dictated by the needs of public safety, not commercial carriers seeking to serve the public. Local governments that are averse to allowing wireless deployments may find themselves being forced to approve a FirstNet site based on public safety needs.

FirstNet technology will look very much like the existing wireless networks, and will use HetNet architectures to provide wide-area coverage from large macro towers, and DAS or Small Cell equipment to provide speed and spectrum efficiency in populated areas.

Early 5G Trials

5G is interesting and potentially very valuable, but 4G LTE technology will be around for many years to come. News stories about early 5G testbeds and trials will increase as we get closer to 2020, after which we’ll begin to see some deployments, but it will be at least another decade before 5G begins to overtake 4G deployments, and 5G subscriptions will not overtake 4G subscriptions until at least 2031. This doesn’t mean we shouldn’t be planning for 5G, just that we should have reasonable expectations for when those systems will reach mass deployment, and not expect that they’ll be prevalent in the next few years.

Recommendations for Municipal Governments

Understand and Adapt to New Telecom Legislation

The FCC Shot Clocks, Section 6409(a), and state laws such as California's AB 57 are the laws of the land. Local governments must carefully consider and prepare for responding to wireless facility applications given the rules passed. The alternative is a lawsuit, which nobody wants and only serves to suppress cooperation on the shared goal of creating world-class wireless networks for our citizens. Local governments must be diligent about creating tools such as a comprehensive pre-application checklist, and publish clear application instructions that "specify the code provision, ordinance, application instruction, or otherwise publically-stated procedures that require the information to be submitted." (Reference to Section 6409(a) on the Spectrum Act 2012)

> "Access to wireless broadband is critical, and both governments and carriers have a shared social responsibility to ensure equitable access for all citizens."

At a minimum, local governments should determine if their existing codes and ordinances address wireless facilities in the public right-of-way – and should quickly take action to create those codes and ordinances if they do not. Due to the unique nature of HetNet facilities, these new codes and ordinances should be separate from any existing ordinances that pertain to large macro towers and equipment.

Recognize the Societal Value of Wireless Broadband

The economics of the Digital Divide are plain and striking – internet use by households below $75,000 median income drops off exponentially. (White House Council of Economic Advisors, 2016) Elementary and secondary school teachers are increasingly requiring students to complete and submit work online via cloud-based tools such as Office 365™ and Google Docs™. Wireless is increasingly the sole method of internet access for low-income households. (McHenry, 2016) How will children of low-income families compete without access to broadband? Access to wireless broadband is critical, and both governments and carriers have a shared social responsibility to ensure equitable access for all citizens.

The California Emerging Technology Fund (CETF) commissions an annual survey of the state's Digital Divide. (CETF, 2016) 74% of survey respondents cited costs of access or equipment as their reason for not having broadband access. The 2016 survey found broadband adoption rates well below the overall state average of 84% for:

- Households earning less than $22,000 (68%)
- Adults 65 or older (56%)
- Spanish-speaking Latinos (69%)

- Not a high school graduate (63%)
- Adults who identify having a disability (71%)

In the past, the thinking was that mobile users are demographically affluent – the stereotypical multi-tasking businessperson with a smartphone, but today's reality is otherwise. Mobile devices have replaced laptops and PCs in many homes. Families in poverty, unable to afford both mobile data and wired broadband, often opt for mobile data only. Wireless telecom and mobile broadband are not luxuries for the wealthy - they are critical systems for all citizens struggling to keep up with (or join) the 21st century. Fast reliable wireless broadband coverage is not a convenience for the privileged few – it is a vital resource which must deployed for use by all citizens.

"Municipal governments need to view communication networks no differently than water or electricity projects."

Some municipal governments view telecom projects as an opportunity to increase revenue, which is misguided. Municipal governments need to view communication networks no differently than water or electricity projects, and they should consider legitimate requests for safe and aesthetically-reasonable communication equipment projects not as a revenue source, but as an opportunity to improve quality of life and bridge the Digital Divide.

Install Conduit, Adopt Dig Once Policies, and Allow Micro-Trenching

The rate at which we consume digital data shows no signs of slowing down. The best technology for carrying large amounts of data is fiber optics. Installing conduit at every opportunity is an inexpensive way to invest in our future, and conduit installed should be oversized and doubled-up whenever possible to facilitate future growth.

Local governments should create "Dig Once" policies that encourage conduit installation, and should create "Opportunity Alert Systems" that notify wired and wireless telecommunication companies when permits are issued for underground work that could allow conduit to be installed. Local governments should also create codes and ordinances that allow for "Micro-Trenching" – a less-disruptive installation process which allows fiber to be deployed using flexible ducts laid into a saw cut only 1.25" wide. (Broadband Properties, 2009)

Stay Informed and Educated

Wireless communications is a complex topic, and it's constantly changing. People who've spent their careers in the field struggle to keep up. There's no dishonor in admitting that you need help, and there are good sources of information and support that can be retained to help guide strategy and tactics. It's important to stay connected with the wireless community. A good way to do this is to attend local conferences, educational seminars, or hosting an

> “By approaching these densified networks not as a problem but as a joint opportunity to improve our networks, we can overcome this challenge and move forward with new technologies that benefit our citizens and local economies.”

informational session with your review and hearing bodies – this helps build a network of contacts that can offer advice and help to understand technologically feasible options and tradeoffs.

Unfortunately in many instances a lack of mutual understanding has arisen between wireless carriers/operators, residents, and municipal governments – causing protracted negotiations and permitting processes that took many months or even years to complete, and delaying projects to the point where projects have become unprofitable or even impossible. Some local governments, acting to appease objections of residents, have treated applications for wireless facilities with disdain or even outright hostility. Municipal government leaders often sit through hours of citizen objections as to why a site should not be located in a certain spot. The reasons for these objections are often based in fears of new technology, concerns over aesthetics, fears about the impact of wireless facilities on property values, etc.

This “not-in-my-back-yard” perspective, which gives excess weight to the opinions of a vociferous minority at the expense of the needs of all citizens, led to industry lobbying for legislation at both the federal and state level designed to force local governments to publish their application criteria up front, not change application criteria in mid-process, make decisions within a set timeframe on applications, and to require negative decisions to be made on a reasonable and equitable basis. It’s unfortunate that these laws have to exist, but they at least will prevent the kinds of stalemates which have too often occurred, and which have prevented us from having the best wireless networks in the world.

The complexities of managing telecom applications and permitting will only increase as the wireless telecom industry moves from applying for permits to erect or modify a single macro towers covering many square miles to applying for permits to deploy densified HetNet networks where many small sites (each covering only a few blocks) are to be installed – often in the public right-of-way on street lights, signs, utility poles, and other street furniture. By approaching these densified networks not as a problem but as a joint opportunity to improve our networks, we can overcome this challenge and move forward with new technologies that benefit our citizens and local economies.

There’s no dishonor in asking for help. Wireless networks are not simple things. Even senior engineers who’ve been doing telecom for decades struggle to keep up with new technologies. Leaders in all departments (planning, public works, economic development, real estate, utilities, etc.) should not be embarrassed to admit what they don’t understand, and should bring in qualified help as needed when sorting out options.

Recommendations for Carriers, Operators, and Utilities

“Carriers and network operators need to understand that municipal governments are responsive to all citizens, and are charged with balancing often-conflicting edicts to move their cities and towns forward in a progressive manner while honoring and maintaining the area’s local history and heritage.”

Understand the Complexities of Local Government

Carriers and network operators need to understand that municipal governments are responsive to all citizens, and are charged with balancing often-conflicting edicts to move their cities and towns forward in a progressive manner while honoring and maintaining the area’s local history and heritage.

Communicate Clearly and Credibly With Citizens

Carriers and network operators need to communicate well with local residents and then commit to hearing out their concerns – even if those concerns might seem ridiculous or uninformed. They need credibly and straightforwardly to educate the public about the value of communications, technologies which are or will be used, and how these have evolved from voice-only to voice & data systems.

Commit to Bridging the Digital Divide

It’s easy and profitable to focus deployment resources on higher-income areas. The harder thing, but the right thing, is to commit to building networks into underserved areas to help bridge the Digital Divide and protect our most vulnerable citizens. It may be that these networks are less profitable, or even take a small loss, but the goodwill they create will ease tensions and concerns, which helps everyone in the long run.

Work to Build and Maintain Trust

Carriers and network operators need to be hyper-vigilant about ensuring that what gets built matches the application and design documentation. They need to actively work to ensure that projects are not done with unpermitted modifications, consider the needs of citizens and neighborhoods, and avoid shoddy workmanship. Do everything possible to avoid building wireless facilities that conflict with architectural or historical preservation efforts. They should choose and use equipment that is smaller, quieter, and minimally visible – and always be pushing their component vendors to develop products that help meet these goals. Communications and openness with residents and local governments about even small changes are the keys to building trust –changes slipped in under the radar are almost always discovered and this gives opposition groups a lot of ammunition to protest new projects, which is ultimately counter-productive.

Takeaways for Municipal Leaders

1. Heterogenous Networks (DAS and Small Cells) are coming. Ask your Planning and Public Works Directors if they have a review process in place for wireless facilities in the public right-of-way. If there is no defined process, work with your City Attorney to craft one (or borrow an example from another city) that meets your needs.

2. Inventory your assets. Get a sense of what utility poles, light poles, and conduit routes your municipality does and does not own. Are certain areas under jurisdiction of another government agency?

3. Reach out. Talk with your local electric utility provider about options for metering wireless facilities, and ways to avoid the need for bulky electric meters or disconnect boxes on sidewalks or poles. As electric power providers often go through rigorous review to update standards, have this conversation early on.

4. Educate. Hold an information session for active community groups, as well as elected leaders and appointed bodies that may have an interest: e.g. Planning Commission, Design Review Boards, Historic Preservation Commission. Provide photo examples of DAS and Small Cell sites installed elsewhere. Invite carrier and utility representatives.

5. Update Infrastructure. Evaluate whether limited-area microtrenching can be used to minimize fiber optic deployment costs and reduce the need for major street trenching activity. This option can benefit both cellular providers, wired broadband and cable TV providers, as well as independent/community-based internet service providers and government agencies. Also, consider creating Dig Once policies to expand opportunities to build fiber optic infrastructure over time. Remember that, for the most part, wireless facilities still require fiber optic backhaul. Fiber and conduit are relatively cheap compared to labor and construction costs, so it's an investment worth making to install fiber and conduit while streets or sidewalks are opened up.

Glossary of Terms

Term	Definition
2G	Second generation cellular.
3G	Third generation cellular.
4G	Fourth generation cellular.
5G	Fifth generation cellular : an ITU recommendation governed by the IMT-2020 standard.
3GPP	Third Generation Partnership Project, a standards body.
ARPU	Average Revenue Per User : a measure of system revenue relative to the number of users – to be profitable, ARPU must be higher than the costs of building and maintaining the network.
Bit	A single unit of digital information.
Byte	A block of 8 bits.
Broadband	Data which transfers at minimum speeds of 25 Mbps download, 3 Mbps upload (Per the FCC's 2015 definition).
CBRS	Citizens Broadband Radio Service : a 3.5 GHz band communications standard for Small Cells, used in the USA.
Cellular	A wide-area wireless technology consisting of many sites interoperating as a network, for the purposes of providing voice and data communications.
Churn	A rough metric of the rate at which subscribers change from one carrier to another.
Co-Location	The installation of wireless equipment and antennas for multiple technologies and/or competing carriers to a single tower or wireless facility.
DAS	Distributed Antenna System : can be indoor (typically just called DAS) or outdoor (usually called o-DAS).
Dark Fiber	Fiber optic cabling which is unused and reserved for future use.
dB	Decibel, a unitless ratio of gain or loss.
dBd	Decibels of antenna gain relative to a simple dipole antenna.
dBi	Decibels of antenna gain relative to a theoretical point-source antenna.
dBm	Decibels of power gain or loss relative to a milliwatt of RF energy.
EB	Exabyte, $1x10^{18}$ bytes.
FCC	Federal Communications Commission.
FirstNet™	A nationwide network of LTE sites reserved for use by public safety and critical infrastructure users.
GB	Gigabyte, $1x10^{9}$ bytes.
GHz	Gigahertz, $1x10^{9}$ hertz.
Gig Economy	The economic shift of workers away from full-time long-term employment to transient short-term jobs or "gigs" – sometimes called the Contractor Economy.
Handoff	The process by which a wireless voice or data connection is seamlessly transitioned from one site to another.
HetNet	Heterogeneous Network : a system of dissimilar wireless technologies operating as a whole.
Hz	Hertz (cycles per second) : a measure of frequency.
IEEE	Institute of Electrical and Electronics Engineers : a standards body.
IoT	Internet of Things : the connection of stand-alone nodes, systems, and devices to the internet.
IP	Internet Protocol : the standard for data communications over the internet.
IT	Information technology.
ITU	International Telecommunications Union – the technology standardization and coordination arm of the United Nations.
Lattice Tower	A type of communications tower constructed from a lattice of metal sections – can be either guyed (GT) or self-supporting (SST).
Lit Fiber	Fiber optic cabling which is operated by a company that sells capacity on that fiber to multiple users.

Term	Definition
LPWA	Low Power Wide Area : An Internet of Things communications technology that uses low-power, low data rate communications for devices.
LTE	Long Term Evolution : the name for the "4G" radio interface standard published by 3GPP.
LTE-A	LTE Advanced : a higher performance version of LTE.
LTE-LAA	LTE-License Assisted Access : a 3GPP-compliant LTE-U technology.
LTE-U	LTE-Unlicensed : a technology to run LTE waveforms on the 5 GHz unlicensed spectrum band.
Macro Site or Tower	A large tower (either guyed or freestanding) which supports communications equipment and antennas.
Mbps	Megabits, $1x10^6$ bits per second.
MBps	Megabytes, $1x10^6$ bytes per second.
MHz	Megahertz, $1x10^6$ hertz.
Mobile Economy	The exchange of goods and services delivered to consumers by smartphone apps.
Monopole	A type of wireless tower.
MSO	Multiple System Operator : an operator of multiple cable or direct-broadcast satellite television systems.
mW	Milliwatt, 1/1000th of a watt.
NFV	Network Functional Virtualization.
NGH	Next Generation Hotspot : a standard that allows Wi-Fi devices to use foreign networks without needing to manually log in.
Offload	A network enhancement technique where requests for large amounts of data (such as streaming video) are handled by a parallel network – usually through a Small Cell or Wi-Fi node.
RF	Radio Frequency.
Roaming	The automatic sharing of networks, used to provide subscribers with a larger number of available sites without requiring user intervention.
SDN	Software Defined Networking.
Sharing Economy	Ride-sharing from individual contractors (as an alternative to taxi or livery services), Home-sharing from private citizens (as an alternative to hotels or motels), and other models – these are managed and enabled by smartphone apps and mobile networks.
Small Cell	A type of communications equipment which operates at lower power levels than a macro site. Small Cells typically cover areas from a single room up to several hundred meters in radius. They are often attached to other structures such as building roof perimeters, street lights, and utility poles.
Spectrum	The range of RF frequencies used by a wireless system.
VoLTE	Voice over LTE.
VoWiFi	Voice over Wi-Fi (sometimes referred to as "Wi-Fi calling").
Watt	A measure of power, used to define RF power levels.
Wi-Fi	Wireless Fidelity : the IEEE 802.11 standard for data communications.
Wi-Fi First	A type of wireless subscription model where the subscriber equipment prefers to use Wi-Fi calling (VoWiFi) for voice connections. If Wi-Fi is not available, the voice call is handled by a cellular carrier via a roaming agreement.
Wireless	Telecommunications of voice or data using RF methods.

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