# Wireless Infrastructure as the Foundation of Smart Cities and Communities

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# Content



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# Abstract

More than 80 percent of North Americans live in urban areas and are increasingly concentrating in mid-sized and large cities. This trend is expected to continue as economic forces, industry drivers and other factors drive people toward urban areas.[1]

Faced with increased populations, cities are challenged to create more efficient ways to deal with the impact of this growth while being sensitive to environmental, economic and quality-of-life issues. Connectivity and bandwidth are fueling a new Gigabyte economy that will rely on smart services. Wireless and fiber-optics are key enablers of that connectivity and will play essential roles in creating smart communities.

Today's wireless infrastructure — while robust — will require massive upgrades. Technical advances in speeds, location awareness, coverage, capacity, range, and a multitude of other areas will be needed to support the estimated 25 billion connected devices that could be in use by 2020, according to Gartner. Aligning policy and capability is essential to enabling the successful implementation of these technologies. This requires governments to break down departmental silos, build partnerships and look to best-practices models that are proven to be successful. This report will explore the infrastructure needs of building smart communities.

# Introduction

Wireless has grown from a voice-only, person-to-person, mobile communications service to a rapidly evolving, highly connected mobile broadband world where everything will be able to connect to everything else. This is frequently called IoT (Internet of Things) or IoE (Internet of Everything). From smart power grids to connected cars that autonomously traverse streets, massive amounts of mobile broadband data will be required. A heterogeneous network (HetNet) of technologies will be required to meet the challenge of providing enough coverage and capacity to power these advances. Simultaneously, the world's population is becoming more urban than ever. Approximately 82 percent of North Americans live in urban areas and increasingly are living in mid-size and large cities, according to Grayline, a consulting group that helps companies and public institutions manage disruptive change.[2]

Faced with increased populations, cities are challenged to create more efficient ways to deal with the impact of this growth while being sensitive to environmental, economic and quality-of-life issues. Today's forward-thinking municipal leaders are using technology to become "smart," i.e., using technology to increase efficiency and reduce waste.

Wireless infrastructure needs to get closer to the end user to handle additional capacity. This requires creative use of existing infrastructure, such as bus shelters, building rooftops, light poles, streets, ducts, tunnels and towers. It may also require new regulations and methods to embed sensors, cameras, radios and other "things" that will form the platform of a smart community. Close collaboration between municipalities and infrastructure stakeholders will be required.

Several major areas that can be addressed by smart communities today and in the coming years are:

- Public Safety
- Equity of Municipal Residents
- Sustainability and Resilience
- Transportation
- Energy
- Water
- Waste

This report will touch on those key areas as well as the role of infrastructure, policy initiatives and financial options for building a smart community.

# Public-Safety Needs

First responders need reliable radio coverage no matter where they are, including on the street, in buildings and in tunnels, both for the public's safety and their own safety. Clear communication in times of crisis is imperative to successful outcomes. In-building and in-tunnel communications are key concerns for both public-safety agencies and tenants. Providing reliable coverage in those environments is particularly challenging and requires knowledge and expertise in the specialized systems designed to meet those needs.

## First Responder Safety

Radios are lifelines to first responders. Firefighters and police officers use portable radios as their primary communications devices. That means ubiquitous coverage is expected wherever handheld radios may be carried: streets, basements, high-rise buildings, parking structures and more.

Common objectives in designing reliable public-safety communications networks are to reduce emergency services' response time, provide local alerts for crime activity, assure user-focused mobility services for the disabled and handicapped, and have a network that can be upgraded to support futuristic services. For example, fifth-generation (5G) technology advancements will enable enhanced communication between first responders and emergency service personnel providing information to their coworkers at the scene. 5G will provide the technology for significant amounts of data to be transferred at low latency and high quality, allowing first responders to have wireless access to building drawings or other critical information within seconds of a request. The technology also will allow first responders to send back video or pictures via helmet cameras or other wireless devices in real time to personnel at command centers who are organizing ground efforts, working to coordinate resources and ensuring emergency personnel safety.

For more than a decade, many jurisdictions have enacted ordinances requiring minimum levels of coverage for public-safety communications within enclosed areas such as tunnels, parking garages and buildings. Mandatory codes for public-safety communications vary from jurisdiction to jurisdiction. However, two widely accepted and enforced code rules are the International Fire Code (IFC) and the International Building Code (IBC).

### The Public's Safety

Society has embraced cellular connectivity for public safety. Over the past decade, the percentage of 911 calls made via wireless devices has increased compared to those made on landline phones every year. About 80 percent of consumers used cellular phones to make 911 calls, according to 2016 data from reporting states, while about 16 percent used wireline phones.[3] Because most Americans rely on wireless networks to contact public-safety personnel, a strong infrastructure is necessary for next-generation emergency services to function.

In addition to basic emergency services requested today via wireless devices (ambulance requests, police and fire calls, traffic accidents, reports of criminal activity, etc.), the future of wireless technology will provide a more robust suite of emergency services and safety features. 5G cellular technology will be able to provide enhanced location-based services for indoor 911 calls, where most originate. Software providers and equipment companies are developing solutions that aim to provide a position accurate to two meters from a caller's location, including vertical location for calls made from high-rise buildings. Next-generation network solutions also will provide a more robust coverage footprint versus current Global Positioning System (GPS) protocols as well as a lower latency time to generate an exact caller location. These solutions will be vital in improving location-based accuracy for first responders, dramatically improving response times during life-threatening situations.

## Equity of Municipal Residents

The economics of providing ubiquitous wireless service are challenging, as more dense areas provide a more rewarding environment to attract capital investment. Moving forward, 5G deployments are likely to occur first in areas where private investments are best justified.

Providing broadband to underserved urban and rural areas will remain a dilemma until more public and private funding sources are identified along with the removal of regulatory barriers. Education, online training, health services, financial services, news and information, security, and many other vital tasks and services are now delivered through fixed and mobile broadband wireless communications networks using Wi-Fi or a commercial cellular carrier's network. Data shows that unemployment is higher where broadband adoption is lowest. Household income suffers, along with education rates.[4]

We need to avoid a digital divide that segments the population into those with robust wireless service and those without. The reality is that lack of robust infrastructure can lead to a significant disparity of available services for underserved residents. Significant investment in broadband wireless connectivity is needed to prevent any disparities.

## Sustainability and Resilience

In many cities and communities, sustainability is a core driver for smart-city initiatives. Water, energy, waste and transportation have generated initiatives that use connectivity and data analytics to change processes and systems. These new systems provide enhanced services while achieving economic and environmental efficiencies. In addition, the change to "smart" can help fortify critical infrastructure that is susceptible to water, wind, fire and other forms of disaster.

Smart services are delivering significant returns on investment (ROI) today. The smart grid, smart meters and time-of-day pricing tools have changed the energy industry. These technologies rely on networks to collect, analyze and in some instances, generate action using a combination of sensors, connectivity, big data and devices.

Smart buildings that are LEED certified attest to a building's "green" value. Wireless networks operate throughout the buildings to monitor air conditioning and cooling, heating, lighting and water utilization through a series of strategically placed sensors. Cellular, Bluetooth, Zigbee and other network protocols provide the necessary level of connectivity to impact real-time results. Programs like the Better Buildings Challenge have demonstrated ROI and improved performance while achieving more sustainable operations.[5]

In outdoor environments, lighting and waste innovations are also incorporating telecommunications network gear and sensors. Smart poles, solar-powered trash bins and smart street kiosks use new form factors to provide increased efficiency and functionality.

Likewise, transportation and carbon emissions are of concern to many cities. Smart parking apps utilize network technology and applications to assist drivers in locating a parking space more efficiently, which limits the amount of gas used and carbon emitted.

## Transportation

Connected vehicles using high and low bandwidth, with human control as the redundancy in case of emergency, is one vision of the future. The automotive sector is an important developmental segment for 5G wireless technology and may prove to be the ultimate test for it. There are a variety of use cases for mobile communications for vehicles. For example, entertainment for passengers requires simultaneous high-capacity and high-mobility mobile broadband regardless of location and speed. At a minimum, the technical requirements for self-driving vehicles must include ultra-low latencies and ultra-high reliability, increasing traffic safety to levels that humans cannot achieve themselves. Assisted-reality dashboards are fast becoming another application for the vehicle. The dashboard will overlay, and augment, the information on top of what the driver sees through the front windshield. As an example: assisted reality will be able to identify objects in the dark and inform the driver about the distances and movements of those objects.

These use cases are related to content for the vehicles' users. However, the cars themselves also will be connected. Driverless public-works trucks emptying trash cans, or city buses transporting passengers on pre-established routes can be a reality. Electrically powered vehicles can receive and send power from the grid, improving mileage.

Many vehicle manufacturers are adding driver-assistance systems based on 3D imaging and built-in sensors. In the foreseeable future, wireless sensors will enable communication between vehicles, as well as information exchange between vehicles and the supporting infrastructure. Next steps include communication between those vehicles and other connected devices like those carried by pedestrians or implemented by private and government entities.

Roadway condition detection systems will be enabled with a connected transportation network and include cars detecting safety-critical situations, such as snow or black ice, accidents within reach of the car, and other hazardous road conditions like large potholes and road workers. Safety systems also will assist drivers on alternative options, such as traffic mitigation, and allow them to drive more safely and lower the risk of accidents.

Additional areas of the transportation sector that will be directly impacted by high-speed broadband and the implementation of sensors include:

- Traffic flow optimization;
- Parking efficiency and payment;
- Facilitation of the movement of goods in cities;
- Conversion of existing infrastructure (utility poles, traffic signals) into new infrastructure for small cells;
- Waste management;
- Light-rail sensors to optimize people movements; and
- Pedestrian directions and event coordination (street-level smart infrastructure).

# The Role of Infrastructure in Smart Communities

As more people embrace the mobile-first society, wireless carriers have had to use a combination of more spectrum, new network technologies and densification efforts to bring added network capacity and coverage for their customers, including deploying more Distributed Antenna Systems (DAS) and small cells to bring the network closer to the end user. It's important to note that DAS networks (along with other wireless applications and access technologies) are a complementary solution to macrocellular sites, and not a replacement. Over the last decade, economic, regulatory and operational concerns have prompted wireless carriers to look for complementary wireless technologies and solutions that would reduce their need to deploy macrocellular sites and installations on towers. With each technological advance in wireless radio networks, however, subscriber growth, changes in user behavior and user expectations have only increased the need for more macro sites deployed on towers and rooftops. Smart communities will need more wireless connectivity, as well as a robust fiber foundation, to match the smart community vision with reality.

# Fiber

A fiber backbone is a key foundational component of any smart community. While fiber networks span the globe, connecting communities that are continents apart, the scope of fiber networks addressed within this report include metro fiber and dark fiber that will address the need for further densification of fiber networks within communities to support the higher number of wireless network access points, wireless devices and end users.

Fiber networks enable a myriad of smart-community solutions. Wireline fiber networks provide high-speed broadband services used by educational institutions, public-safety officials and hospitals. Whether a device is connected via licensed spectrum or unlicensed spectrum, fiber networks play a critical role as the "backhaul" network for all mobile, fixed-wireless and other forms of wireless networking. According to Cisco's 2017 Visual Network Index Forecast, wireline networks support nearly 90 percent of all Internet traffic, the majority of which is generated by wireless devices.[6] Today, smartphones account for a large source of wireless-originated Internet traffic, but the adoption of IoT devices will only increase wireless-originated traffic.

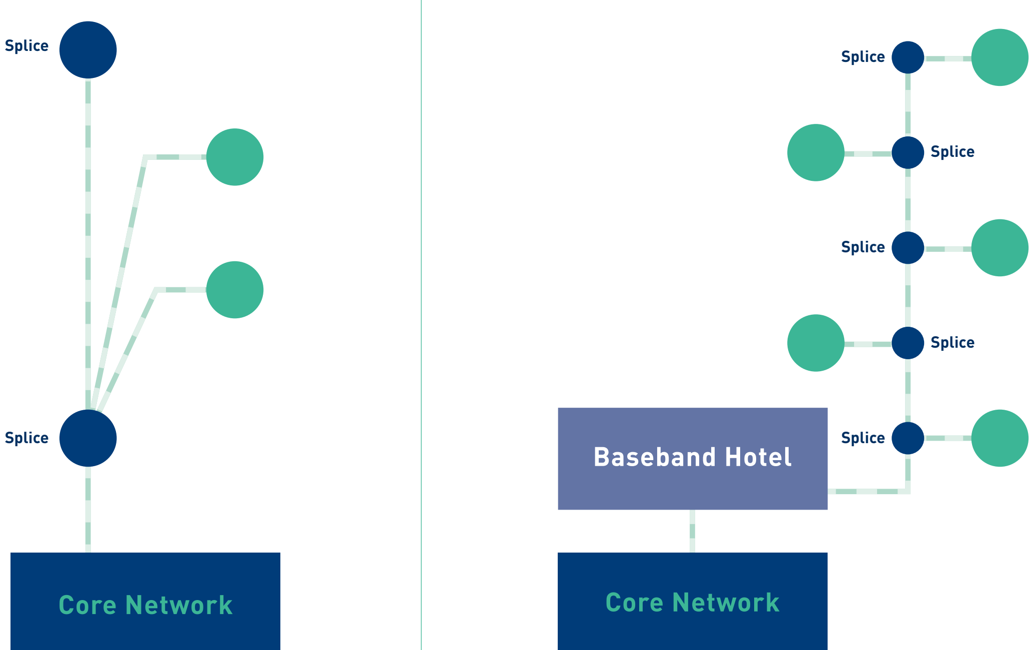
As wireless traffic continues to grow, additional fiber network infrastructure must be deployed to meet the projected demand. A 2017 report by Deloitte Consulting LLP states that "Unlocking the full potential of 5G in the United States rests on one key assumption: the extension of fiber deep into the network."[7] 5G promises higher mobile data rate speeds, including several hundreds of Megabits per second (Mbps) in urban environments and 1 Gigabit per second (Gbps) or higher in indoor environments, all of which will require supporting fiber networks that can meet capacity increases as wireless traffic grows. Without additional fiber network infrastructure deployments that reach deeper into metropolitan centers and edge communities, Deloitte's report also asserts that "carriers will be unable to support the projected four-fold increases in mobile data traffic between 2016 and 2021."

Due to the increase in wireless traffic, dark fiber network operators, or operators that deploy high-capacity fiber networks and then lease capacity (in the form of number of fiber strands) to customers ranging from enterprises to mobile network operators, have become significantly important to addressing wireless traffic growth. These fiber networks are only activated – or lit – when their customers need increased bandwidth.[8]

Legacy fiber backhaul networks are typically built with relatively low fiber capacity that is heavily multiplexed with dense accessibility (e.g., fiber-to-the-home networks), or high fiber capacity and sparse accessibility (e.g., enterprise fiber networks). Also, backhaul networks in a typical dense urban environment are designed for lateral splice locations every few thousand feet.

DENSIFICATION CHALLENGES

**Legacy Network** vs. **Next-Generation Fronthaul**




*In the legacy networks, splices can take place every 3,000 feet.*

*In the next-generation of fronthaul networks, fiber splices could take place every 250 feet or so.*

***Source:*** *Ray La Chance, ZenFi*

To obviate the limitations of legacy networks, a new fronthaul access network must be architected differently, with high fiber capacity as well as easy accessibility, allowing for lateral splices every few hundred feet or less. Such a fronthaul network must also provide relatively short links to interconnect the baseband processing to the distributed RF interface locations to meet stringent latency requirements. The new fronthaul network architecture primarily differs from legacy backhaul architectures due to the density of fiber lateral splice points necessary and the number of dedicated fibers required to serve each end point. To visualize the difference between backhaul topology and the front network topology, think of the backhaul network as an expressway with sparsely spaced onramps and the fronthaul network as the local roadways with a collocation facility acting as the interface between the two network topologies. The "Network of Neighborhood Networks" model offers an analogy with the legacy central office topology where large voice switches are replaced with baseband processing cloud equipment and the 2,400 pair copper trunks are replaced with 1,728 or greater fiber-optic cables (3,456 fiber cables are shipping today). Similar to legacy copper plant, the fiber network must taper down as it becomes an access network and routes along the neighborhood streets, providing accessibility everywhere along its path. However, unlike the copper plant, which is more easily intercepted and spliced into, to enable the new network model, innovative techniques for ducts, cables and fiber splicing must be developed to support the unique nature of fronthaul access topology.

Key points that can be extrapolated from the section above are as follows:

- Most 5G experts foresee an infrastructure that requires extreme densification to achieve the goals for downlink speeds, latency and coverage;

- The existing backhaul fiber infrastructure, supporting legacy Distributed RAN architecture, is not sufficient to support the dense C-RAN deployments on the horizon;

- A significant financial investment must be made in high capacity, highly accessible fronthaul networks and distributed baseband collocation facilities.

# Street-level wireless infrastructure

Street furniture is a term used to define vertical objects in public spaces that – in the context of wireless infrastructure – can accommodate an antenna, radio equipment and/or other sensor equipment and are considered visually commonplace and acceptable to the public. Street furniture to be used for this purpose must have a power source and fiber connectivity for the wireless equipment to function. Common examples of street furniture outfitted for wireless networks include billboards, lamp posts, kiosks, phone booths, mailboxes, park benches, public art, utility poles, athletic field light poles, traffic signals, retrofitted bus-stop stations and other structures in the public right-of-way.

Good design and engineering is crucial to successful small-cell deployments on street furniture. The aesthetic features of street furniture installations must be carefully considered and worked out with local jurisdictions and townships. In a future world of many small cells and thousands of IoT sensors installed all over urban areas, it is conceivable that each major intersection could be inundated with many street furniture installations. Therefore, concealed and stealth-type designs that do not unreasonably increase the cost of deployment could be a design option.

## Utility Pole Attachments

Utility poles are often desired street-level furniture for wireless infrastructure for the following reasons:

- Where local utility service is provided via overhead pathways, utility poles are often well-positioned to serve as wireless infrastructure installation sites. The number of sites available provides design flexibility and antenna attachments at appropriate heights.

- Utility pole owners typically understand joint-usage rules and have existing processes that new parties attaching to their poles can follow to reduce the deployment timeline.

- The utility pole infrastructure likely already contains power service and backhaul pathways, both of which are needed for small-cell deployments.

### Smart Poles

In some cases, new poles can be effective in providing wireless coverage. When integrated into the network deployment strategy from the start, these "smart" poles can be designed as structures that blend into the environment, may carry the required telecommunication equipment internally inside the pole and provide opportunities for new technologies offered in the future. Examples include smart poles that are designed to offer more energy conservation through LED lighting, reducing energy and maintenance expenditures while providing broadband connectivity to residents.

Source: Comptek

Source: Comptek

# Infrastructure Collocation

To support small cell speed-to-market efforts, operators deploying wireless technology on public rights of way or existing private structures can work with infrastructure partners that offer already-approved sites from a permitting, fiber and power perspective.

Timely access to these types of qualified sites and assets makes it quicker and easier to find locations to deliver wireless solutions to users and enable smart cities. It also shortens the time spent negotiating with multiple structure owners, and reduces the effort required to secure the necessary permissions and approvals.

Local jurisdictions should make their infrastructure, including street furniture, available for collocation (the shared use of wireless infrastructure by multiple carriers) to reduce visual clutter and avoid unnecessary duplication of infrastructure. Collocation is today's industry norm, and it works well both for the industry and for communities. The practice of sharing infrastructure offers an ordered and transparent process for all industry players. This streamlined approach helps level the playing field while also lowering barriers for new entrants, encouraging competition in support of increased innovation. Shared wireless infrastructure minimizes the need for infrastructure, which is a practice that is supported by the environmental, historic and cultural preservation communities.

Cities should encourage locating wireless communication facilities on existing structures to reduce the number of new communication structures needed to serve their communities. An antenna that is attached to an existing building with any accompanying pole or device that anchors the antenna and/or radio to the existing building along with associated connection cables and an equipment facility (which may be located either inside or outside the existing building) usually supports a streamlined and expedited permitting process.

The use of stealth technology that disguises wireless communication facilities to fit into the natural or urban landscape will also benefit in a streamlined deployment process. Furthermore, to solidify a favorable permitting process, proposed small cell deployments should be designed and sited to complement urban residential areas, as well as historic and scenic corridors, and not impact the city's current and future beautification conditions.

## Power Requirements of Infrastructure

For pole infrastructure and street furniture to be part of a carrier's wireless network, it must have power and the ability to backhaul traffic, meaning that it distributes the RF signal from the edge of the network back to the operator's core network. Some carriers also require back-up power sources. Back-up power requirements largely have been set by network providers and vary from small solar-powered solutions to a centralized Direct Current (DC) power hub.

## Buildings

Small cells and IoT sensors typically do not require as much height as macro sites. Therefore, shorter buildings can be ideal locations for installation of these types of equipment. Building rooftops and exterior facades can be integrated into the deployment of smart city networks. Today, most buildings in urban cities have fiber installed to serve enterprise or residential tenants' needs for high bandwidths and Internet services and are equipped with adequate power to host telecom installations. Educating the building managers and owners on the appropriate expectations for these smaller installations will be key to making these existing locations available for such deployments. Appropriate construction methods must be used to avoid damaging the rooftops or the facades of these buildings and causing problems for property owners and managers.

# Financing Options

Financing smart-community initiatives is complex and there is no one-size-fits-all solution. Each municipality, government and/or entity must understand its own financing structures, limits and opportunities as a starting point.

A strategic plan around the objective(s) is vital, particularly when funding is limited. Phasing in projects should be viewed as a viable alternative in achieving the long-term vision when funding is not available to cover everything at once.

An important part of being a smart community is being smart with finances; utilizing a broad perspective through procurement processes. No longer can it be just a public works project or just a parks project, so leaders should ask how can a system or a solution be most effectively and efficiently utilized across departments and agencies.

Network infrastructure is capital intensive and requires technical expertise and specialized tools to operate and maintain. There are several potential funding options, including using public-private partnerships (PPP) or leveraging government programs and/or funds already received for infrastructure.

Three types of PPPs include:

1. Design, Build, Operate, Maintain (DBOM). This form of project has a private partner take complete responsibility for a project in exchange for fees from the government. The government finances and owns the project in most scenarios. Fees are generated either via fixed method or a percentage of revenues from end user fees.

2. Joint Venture-DBOM plus private financing and ownership stake. In this scenario, the government and the private investors form a new corporation called a Special Purpose Vehicle (SPV). Private equity is the first at-risk capital, but in exchange, the upside is often greater than the return they would get on other forms of investment.

3. Privatization. In this scenario, the private sector takes over existing assets and operates, maintains, finances and owns the infrastructure with the promise of improvements and performance guarantees. The government grants a private entity, a concessionaire, the exclusive right to operate a network or data center for a set period. In effect, the private entity owns the facility for the life of the concession contract, which often spans 20 to 50 years.

PPPs are gaining traction due to a variety of factors, including:

- Cities and municipalities have exhausted their borrowing capacity.
- Private investors are eager to invest in public infrastructure that has a dependable rate of return with anticipated escalations.
- Lack of expertise within the government compared to specialized providers with scale and a track record of innovation.
- Cities and municipalities have a low risk tolerance and thus like to share responsibility for complex capital projects.

The trend is to look to PPPs to finance and operate fiber optics, wireless infrastructure, transportation signals and sensors, street furniture and data centers. The increased demand for this necessary infrastructure is at the core of the smart city and will be vital to building out the promise of 5G and advanced connectivity.

# Conclusion

Smart cities and communities are quickly becoming a reality as municipalities look to provide enhanced public-safety services, sustainability and efficiency within transportation, energy, water, waste and other public services. Broadband connectivity is crucial for cities and communities, both rural and urban, to remain financially healthy and to provide citizens with educational and other opportunities.

These advances will require not only an expansion and densification of wireless networks that serve end users and accomplish connectivity among devices and sensors, but also of the fiber networks that backhaul an increasing amount of wireless data and traffic. Communities should adopt a forward-thinking and cooperative approach to accommodating infrastructure elements in public rights of way and on existing utility and other structures.

In addition, communities must heed a variety of regulatory guidelines and consider a variety of options to fund the buildout of smart city infrastructure. Defining the scope of the project and understanding its goals from the start will ensure communities transition to smart services successfully.

Localities and states around the country have already began to pave the way to ensure that their communities are well-positioned to enjoy the endless benefits that smart cities can bring. More than a dozen states have enacted legislation that would expedite small cell deployment, and more than a dozen more have already begun to consider similar proposals. The joint efforts of the industry, government, and localities to promote standard processes for the deployment of broadband services will ensure that consumer demand for these services can be met and that many of the advantages of smart cities come to fruition in the near future.

# About the Authors

## Jim Lockwood, Aero Solutions

Jim Lockwood is CEO and founder of Aero Solutions, a leading provider of structural engineering, A/E services and tower reinforcement products since 2002 to the wireless infrastructure industry. Aero optimizes macro-cell co-locations on tower structures and buildings and small cell applications on buildings, light poles, utility structures and other street furniture. Headquartered in Boulder, CO, the company has completed over 4,000 co-locations across the United States, Caribbean, Asia and Europe, providing professional engineering, construction management and reinforcing materials. Jim has 15 years of experience in the wireless infrastructure industry and 30 years as an entrepreneur in the engineering, products, and construction industry. He established Comptek in New York in 1998, a provider of structural components and engineered products; and Wind Tower Technologies in 2013. Prior to 1998, Jim was a Principal of J. Muller International, responsible for the firm's Chicago and New York offices and CEO of Egis, Inc. in New York. Jim is a professional engineer, P.E. and holds a BSCE degree from the Univ. of Cincinnati and an MSCE degree from the Univ. of Washington, Seattle.

## Don Bach, Boingo Wireless

Don Bach is a seasoned telecom executive who has spent the last three decades engineering cellular networks. He currently serves as the director of sales engineering for Boingo Wireless' DAS and small cell business, where he is responsible for overseeing the RF design of the company's cellular networks at large public venues around the world. He previously held leadership positions at Verticom and SAC Wireless. Bach's early career began as a technician in the public safety and LMR two-way radio industry, after he graduated from the Electrical Engineering program at DeVry University in 1986. In 1994, he became a system performance engineer on the iDEN Network by Fleet Call, which was later renamed Nextel. He spent 22 years in a variety of RF engineering positions at Nextel, which was acquired by Sprint in 2004. In 2007, Bach left Sprint to start a regional RF Engineering and implementation company focused on DAS networks. In 2012, he sold the company to SAC Wireless. SAC Wireless was purchased in 2014 by Nokia Networks.

Bach is an active member of the Wireless Infrastructure Association (WIA) and plays a key role in authoring numerous WIA whitepapers on wireless deployment trends and next-generation mobile networks.

## Bernard Borghei, Vertical Bridge

Bernard Borghei is the Co-Founder and Executive Vice President of Operations of Vertical Bridge. He is responsible for Vertical Bridge's daily operations, regulatory compliance, vendor management, engineering services, human resources and emerging technologies.

Borghei has over 25 years of experience in wireless industries and before co-founding Vertical Bridge, he served as Senior Vice President and Partner at Global Tower Partners (GTP), where he oversaw domestic and international market operations, including a portfolio of more than 6,500 towers and 12,000 managed properties.

Borghei has also held executive and senior management positions in operations, engineering, sales, supply chain, site development, and customer care at several wireless operators and service providers including SkyBitz, Wireless Facilities, Inc. Western Wireless International, and at Triton PCS where he successfully ran operations across 24 different countries in Europe, the Middle East, Africa, North and South America.

Bernard has a Bachelor's degree in electrical engineering from Villanova University and an MBA in global management from the University of Phoenix. He also serves on the Advisory Board for the Villanova University School of Engineering.

## Bryan Darr, Mosaik

Bryan Darr, founder of Mosaik, serves as President and CEO. Bryan leads the company's growth as a strategic partner to mobile operators, infrastructure professionals and network-dependent solution providers, enabling clients worldwide to deliver a superior network experience. Bryan has spent most of his professional life in the wireless industry and has been an active participant in the industry's evolution. He leads his team in leveraging technology that helps clients make better business decisions daily, through innovative data visualization solutions that provide more accurate tower site evaluations, increased visibility into customer behavior and interactions with wireless networks, and improved customers' network quality of experience.

Bryan was born and raised in Chattanooga, Tennessee, and moved to Memphis in 1980 to attend Rhodes College where he majored in International Studies. Bryan has served in multiple capacities within many leading industry organizations, and currently serves on the Innovation & Technology Council for WIA and the CCA Associate member committee.

### Ray Hild, Triangle Advisory Group

Ray Preston Hild is an accomplished senior management and strategic partnership professional with over 26 years of experience in the wireless industry. He has consulted on several major government and enterprise initiatives and co-authored several industry white papers. Ray has been a member of the WIA Innovation & Technology Council for several years. In addition, he has served on a variety of wireless committees and boards for major industry associations on such topics as: Unified communications, DAS in mid-tier markets, oDAS, mobile broadband, wireless as the 4th utility, enterprise wireless systems and network densification. Lastly, Ray has created the Public Safety Code Guidebook which is meant to track the changing landscape of first responder wireless requirements across the US.

Ray has held management and leadership positions with several prominent corporations over the years. Those include Sprint-Nextel, Corning, Galtronics, Kavveri Telecom and most recently JMA Wireless. He has won dozens of awards over several decades for service and performance. Ray is involved in the Johns Hopkins Mentorship Academy working with teenagers needing guidance in their career choices. He is also invested in supporting those who served through 185 for Heroes, an organization that hosts events for Operation 2nd Chance to help our warriors when they return from duty.

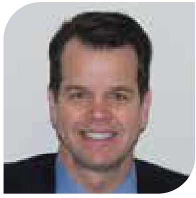
### Rebecca Hunter, Crown Castle

Rebecca Hunter works within Crown Castle's Corporate Development & Strategy group focusing on External Affairs and Strategic Communications. In this role, Rebecca focuses on leveraging Crown's extensive infrastructure resources and deployment experience looking toward emerging technologies and expanding customer opportunities. She represents Crown Castle at various associations including NLC, NaCo, SHLB and TIA.

Rebecca has over 20 years' experience in all aspects of wireless deployment – macros, small cell and fiber. She has worked throughout the United States on local, regional and national scale projects for most of the major wireless carriers and service providers. She has always had a strong focus on government relations and policy, bringing municipal and industry partners together to find mutual solutions to common issues.

Rebecca holds a BA from University of Florida and an Executive MBA from University of Washington.

### Keith Kaczmarek, inPhase Wireless



Keith has more than 30 years of wireless telecommunications experience. His consulting practice, inPhase Wireless, supports early-stage companies bringing new technologies to market. He serves as a general partner at Public Safety Ventures, a private equity firm focused on the wireless public safety networks and critical infrastructure markets. He has been a member of Aero Solutions advisory board since 2006 and has supported their small cell and municipal consulting business. Keith is a recognized expert and speaker at national wireless industry conferences on public safety and advanced wireless technologies. As a member of the Wireless Industry Association's HetNet Forum, Keith participates on the Innovation & Technology Council.

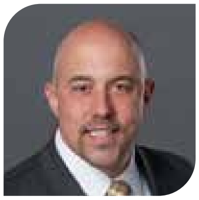
Keith previously held prominent business, technology and operations leadership roles at Intrado, Powerwave, Cyren Call, FiberTower, inOvate Communications Group, Teligent, Nextel, AirTouch, PrimeCo and GTE. Keith was a co-founder of Cyren Call Communications, focused on supporting public safety in the creation of a nationwide public safety broadband network. He was a general partner at inOvate Communications Group, a venture fund focused on early-stage wireless companies. Keith is a Radio Club of America Fellow, holds an MBA degree, a M.S. in Electrical Engineering and a B.S. in Electrical Engineering from the University of Illinois.

### Ray La Chance, ZenFi

As President and Chief Executive Officer of ZenFi, Ray applies proven industry management expertise to deliver cutting-edge communication network solutions to the market. Ray oversees all aspects of business operations, effectively leading a team of experts to solve industry challenges created by the proliferation of mobile data. In addition to Ray's role at ZenFi, he is also a Founding Partner of Metro Network Services, LLC, a company focused on network planning, engineering, deployment and maintenance.

Ray is an Information Technology industry veteran with more than 20 years of experience managing teams to design, build and operate complex, high-capacity networks for large enterprises, financial firms and telecommunications service providers. Prior to ZenFi and Metro|NS, Ray served as President and CEO of Lexent Metro Connect, LLC from 2007 to its successful sale in December 2010 to Lightower Fiber Networks. Ray was also the Co-Founder of Realtech Systems Corp., an enterprise network integration and professional services firm, where he served as President and CEO. Ray received a Bachelor of Science degree in Computer Science from the State University of New York at Albany in 1985.

## Jim Nevelle, Kathrein



Jim Nevelle joined Kahrein in January of 2015 as the president and CEO of Kathrein USA. Prior to joining Kathrein USA, Jim co-founded Sorrento Networks and served as its Chief Executive Officer. Mr. Nevelle has also held management positions at Verso Technologies, Verilink Corporation, and XEL Communications. He is co-author of four U.S. patents pertaining to broadband architectures and deployments and earned a degree in Mechanical Engineering from the University of Washington and a Master's degree in Technology Management from the University of Denver.

## Peter Murray, Dense Networks

Murray was born and raised in New York, New York, and earned a Masters of Business in Information Technology from Fordham University. His major was Utilizing Technology for Competitive Advantage. He graduated from Rutgers College, where he majored in Communications and minored in Parties. He has been General or Regional Manager at Verizon, MCI, Level 3 and Telcove. He has taught E-commerce and Technology for Competitive Advantage at Temple University and helped develop the entrepreneurial program at the Community College of Philadelphia. At CCP, he taught Intro into IT and Intro into Business to inner-city youth and probably learned more than anywhere else he's been. He has three children who text him when they need money. He is the Executive Director of the Social Think Tank, Dense Networks.

## Sam Rodriguez, Aero Smart Communities

Sam Rodriguez is the Vice President of Aero Smart Communities. He is responsible for business development and overall Wireless Development Plan strategies, including joint ventures, and strategic partnerships. Rodriguez joined us from Google Fiber where he held the position of National Wireless Site Development. Rodriguez joined Google from 5 Bars Inside and Motive Telecom where he was the EVP of Wireless Solutions. Prior to that he was part of Verizon Wireless where he served as Senior Manager of the Southern California large venue and small cell strategic network development. Prior to joining Verizon Wireless, Rodriguez was the director of DAS business development of Regional Sales for American Tower and Powerwave. From 2000 to 2009, Rodriguez held positions at Sprint Nextel Communications as network engineering director of the South Region in Austin. During this time, Rodriguez oversaw day-to-day network development and operations and was instrumental in the initial DAS planning and development strategies of over 3500 in-building and outdoor systems. He also has general management experience from 1991 to 2000 with Verizon Wireless, PrimeCo Personal Communications and AirTouch Cellular.

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# Endnotes

1. United Nations World Urbanization Prospects 2014 edition
2. Grayline: Urbanization Catalyst Overview
3. National 911 Program Review
4. Broadband's Impact on Rural Economy
5. Better Buildings Challenge
6. Cisco's 2017 Visual Network Index Forecast
7. Deloitte Study: 5G Ready – The Need for Dark Fiber
8. RCR Wireless News: Dark Fiber Could Mean Deep Savings for Wireless Carriers

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