

A decorative graphic in the top right corner consisting of overlapping, curved, olive-green lines that resemble a stylized globe or a network mesh.

Building Inclusive Municipal Wireless Mesh Networks

Understanding how wireless mesh can and should support a broad range of voice, data and video applications for public access, public works, and public safety.

Overview

The concept of building a municipal broadband wireless mesh network to cover an entire city, metropolitan area or county has been broadly examined in recent years. Literally hundreds of municipalities worldwide have begun to deploy such networks, based on Wi-Fi, public-safety band, and WiMAX technology, and thousands more are in the planning or proposal stages.

Most observers recognize that such networks can offer a myriad of potential benefits. A municipal wireless network can provide inexpensive, ubiquitous Internet access to economically disadvantaged citizens and public schools, an initiative referred to as “digital inclusion” or “bridging the digital divide”. It can spur economic development by making the city more attractive to tourists and businesses. A citywide broadband wireless network can support a variety of mobile applications that greatly improve the efficiency and responsiveness of public safety and municipal workers. Wireless video surveillance can be used to improve public safety. Ubiquitous wireless coverage can help automate, streamline, and reduce the costs of delivering basic city services like utility metering and parking enforcement.

But a municipal wireless network is a large-scale, high-stakes project that demands significant political will, capital investment, and commitment of personnel resources. Careful strategic planning, a clear-eyed assessment of the technical challenges, and consideration of funding options are all essential to make a citywide wireless network a success for municipal government, its employees, businesses, visitors and citizens. Municipalities must find a way to build a broadband wireless network that makes economic sense while addressing the current and future needs of the broadest range of public access, public works, and public safety applications. This paper examines these issues in detail.

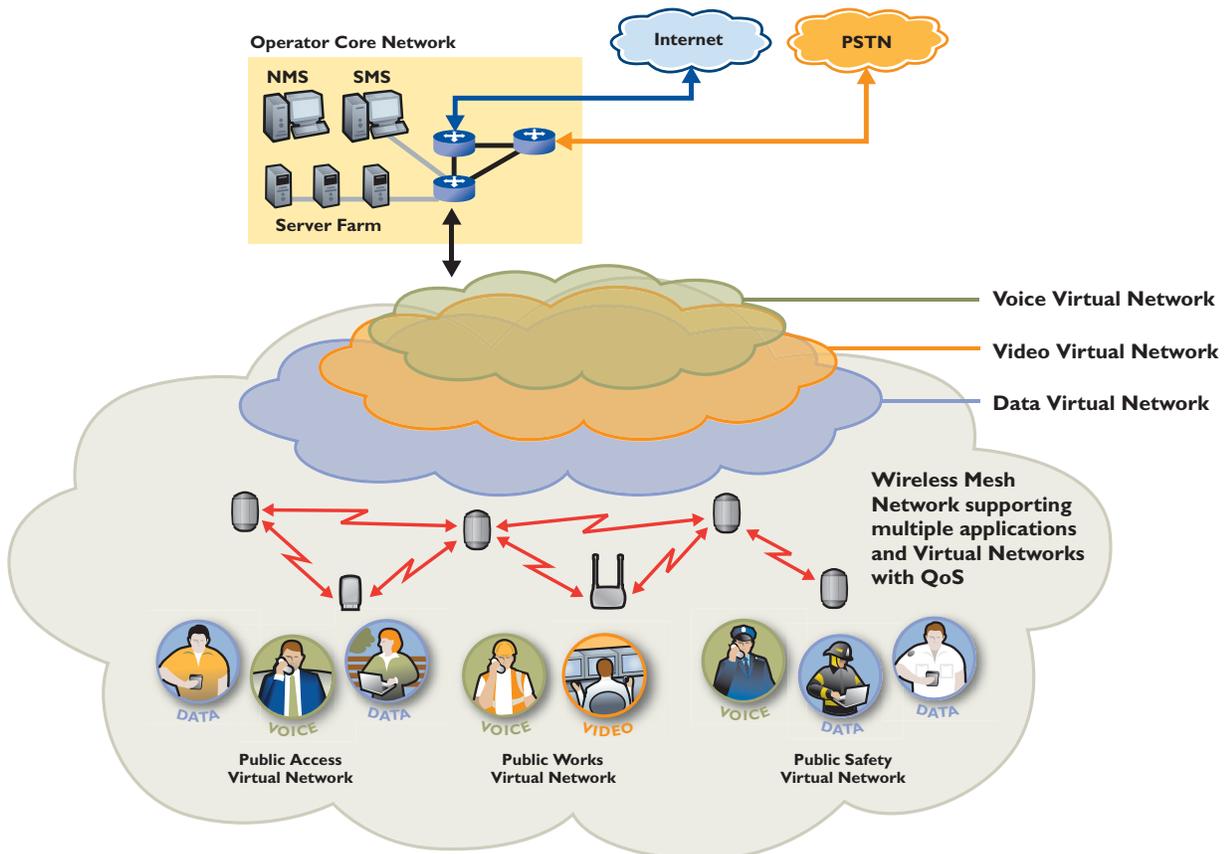
Emerging Municipal Applications

The deployment of municipal broadband wireless mesh networks enables a range of important new applications in three distinct areas:

- **Public access** — providing ubiquitous, city- and/or county-wide access to the Internet and to city-sponsored content at broadband speeds to citizens, students, businesses, and visitors
- **Public works** — providing ubiquitous, secure connectivity to centralized application servers for mobile and remote municipal employees and automated systems in the field.
- **Public safety** — providing police officers, firefighters, and emergency medical technicians, with connectivity from wireless-equipped laptops, handhelds in their vehicles or on their person to centralized application servers; and connectivity for mobile and stationary video cameras for surveillance purposes.

Figure 1 illustrates a municipal broadband wireless network in which all three municipal applications are simultaneously supported.

Figure 1: A municipal wireless mesh network provides public access, delivering high-speed broadband to residents, visitors and businesses while supporting municipal workers and public safety personnel



Public Access Applications

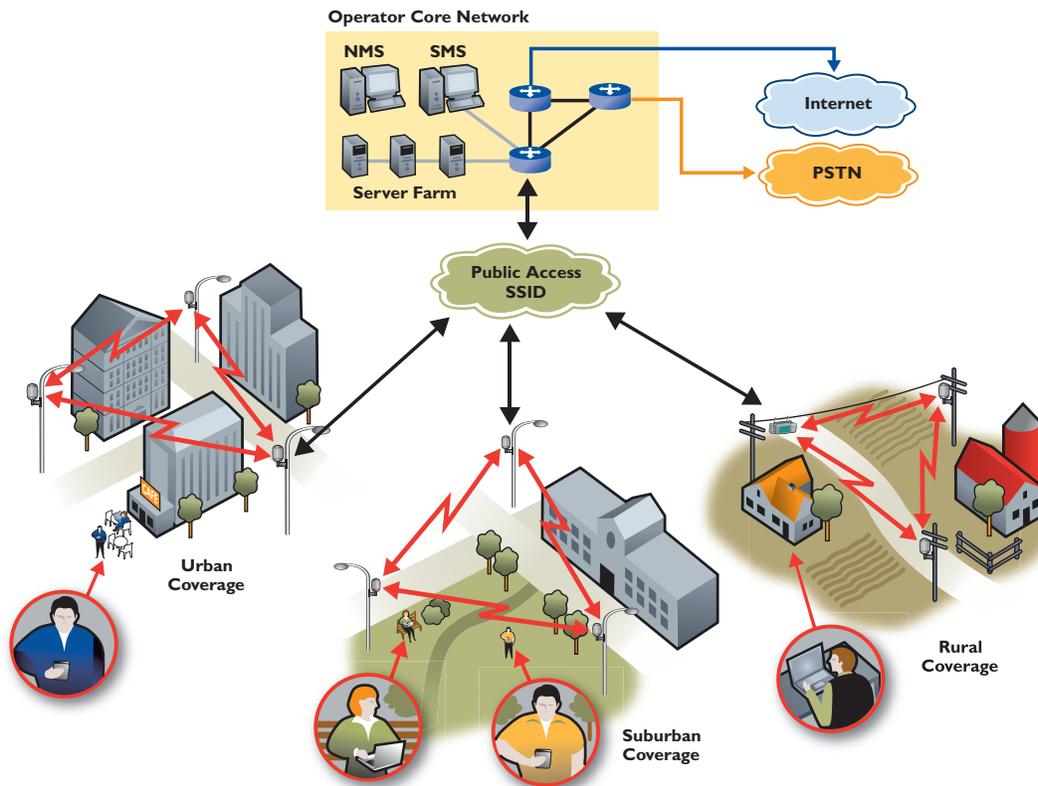
Ubiquitous wireless coverage, primarily using Wi-Fi technology, allows a broad range of end-users (citizens, students, tourists, businesses) to access the Internet at high speeds (up to 1-8 Mbps) from desktop PCs, laptops, and Wi-Fi equipped handhelds, including:

- **Public Internet access** — tourists, visitors, citizens access the Internet in retail districts, financial / business districts; government buildings (city hall, library, post office); leisure spaces (parks, waterfronts); convention centers; and resorts (ski areas, golf courses). Payment can be made on an hourly, daily, or monthly basis. Connectivity may be offered to citizens for free, or at rates that are well below the market rate for competing broadband access technologies like DSL or cable, addressing the issue of digital inclusion for economically disadvantaged citizens, and providing coverage in rural areas not covered by DSL or cable. Some connectivity may be subsidized through the delivery of advertising when users connect, periodically throughout their session, and even with location awareness to promote businesses near the user's current location.
- **Internet access for local businesses to spur economic development** — cost-competitive, ubiquitous Internet access is used to encourage businesses of all sizes to move into or stay in city; attract tourists and shoppers into business districts to meet, dine and shop; promote the city's image as a leading-edge, technology-centric, business-friendly locale; and encourage the use of Internet access for career development, productivity and online commerce purposes.
- **Internet access for public schools** — free or low-cost Internet access in schools allows students, faculty, and administrative staff to more effectively access news, conduct research, and take advantage of e-learning applications. Web-based collaboration allows for more effective interaction and involvement of parents with teachers regarding their children's education.
- **Internet access on public transportation** — citizens and visitors can access the Internet at public transportation stations (depots, terminals, and docks) and in public transportation vehicles (buses, trains, ferries). Commercial advertising, video entertainment, and information about municipal services and tourist attractions can be delivered to a captive audience to generate revenue and fund the wireless infrastructure.
- **New businesses and services enabled by the availability of wireless broadband infrastructure** — for example, a municipality or a municipal Wi-Fi network operator can offer mobile voice services (via VoIP on Wi-Fi equipped handsets and laptops) to municipal employees, citizens and visitors as a lower-cost or free alternative to cellular voice services.

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Figure 2 illustrates a range of public access uses of a municipal broadband wireless network, including high-density urban neighborhood, open public spaces, and lower density residential neighborhoods and rural areas with outdoor wireless coverage reaching into buildings and homes.

Figure 2: A wireless mesh network can provide secure, high-speed public access to the Internet for urban, suburban and rural communities



Public Works Applications

Ubiquitous, secure wireless coverage allows the municipality to greatly improve employee efficiency, replace costly wireline connections, and reduce the operating costs of delivering municipal services in two key areas: municipal employee mobility and automation of unattended services.

A broadband wireless mesh network enables a municipality to arm its employees in the field with mobile applications running on Wi-Fi equipped laptops and/or handhelds, greatly improving their efficiency and responsiveness:

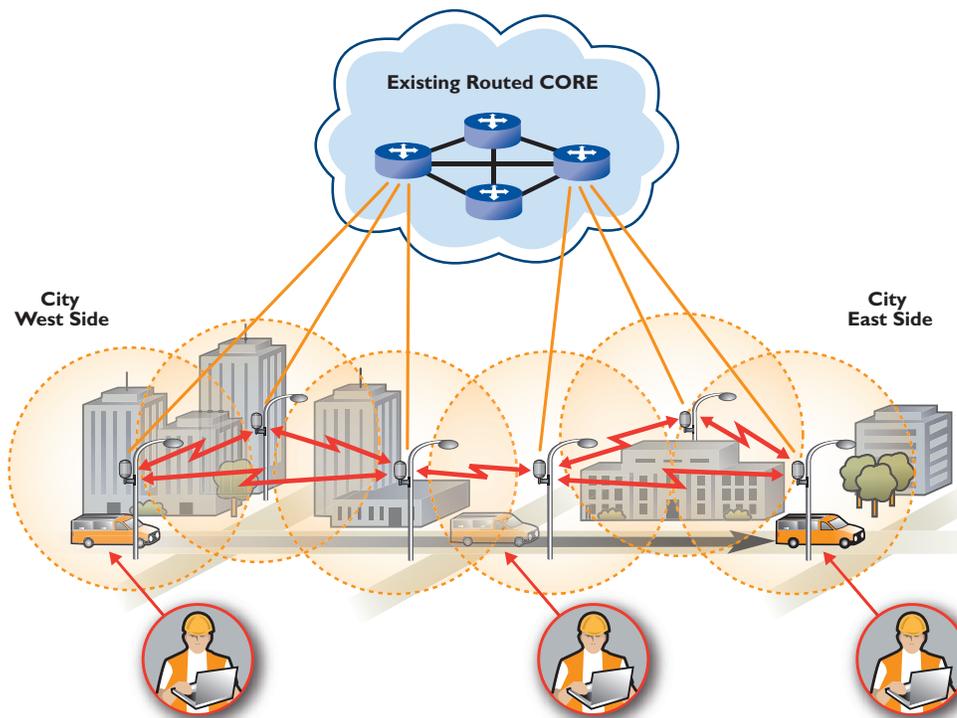
- **Mobile employee applications** — municipal employees who spend most of their time in the field can be equipped with mobile applications on wireless laptops and handhelds, allowing them to make much more effective use of their time and be more responsive to citizens and businesses. Examples include inspectors (construction permitting, fire code compliance, restaurant health, elevator safety, etc.), meter readers, and social workers. These employees may conduct business, access centralized databases, and file reports from the field without returning to office, increasing the number of calls they can make per day. Field-based collection and wireless transmission of data eliminates the duplication of effort and transcription errors

entailed by manual data collection in the field followed by data entry at the office. The capture and attachment of video and still images can greatly improve the efficiency and collaboration of casework (e.g., construction site inspections) requiring follow-up by multiple employees.

- **Fleet and maintenance crew dispatch** — public works repair and maintenance crews for services like roads, sewers, drinking water, and flood control can more effectively be scheduled, dispatched, monitored, and redeployed in real-time. Crews can file status updates and reports from the field, and access helpful information from centralized databases, without having to physically return to base.
- **Mobile employee instant messaging, email, and voice** — municipal employees can reduce cell phone costs and collaborate more effectively by using Internet-based communications tools (VoIP, IM, and email) from their wireless-equipped laptops and handhelds in the field. These mechanisms can serve as useful communications back channel as well as a backup in the wake of disasters that knock out cell phone service (Wi-Fi services are usually restored much more quickly). They also provide a highly interoperable means of inter-departmental and inter-agency communications compared to proprietary, often-incompatible private mobile radio systems.
- **Employee telecommuting** — municipal employees telework from home during off-hours, on flex-time, and during weather emergencies or disasters.

Figure 3 shows how a broadband wireless network supports mobile municipal workers' ability to send and receive information they need to do their jobs more effectively while in the field.

Figure 3: High performance wireless mesh provides an unprecedented level of seamless mobility to municipal personnel on the move

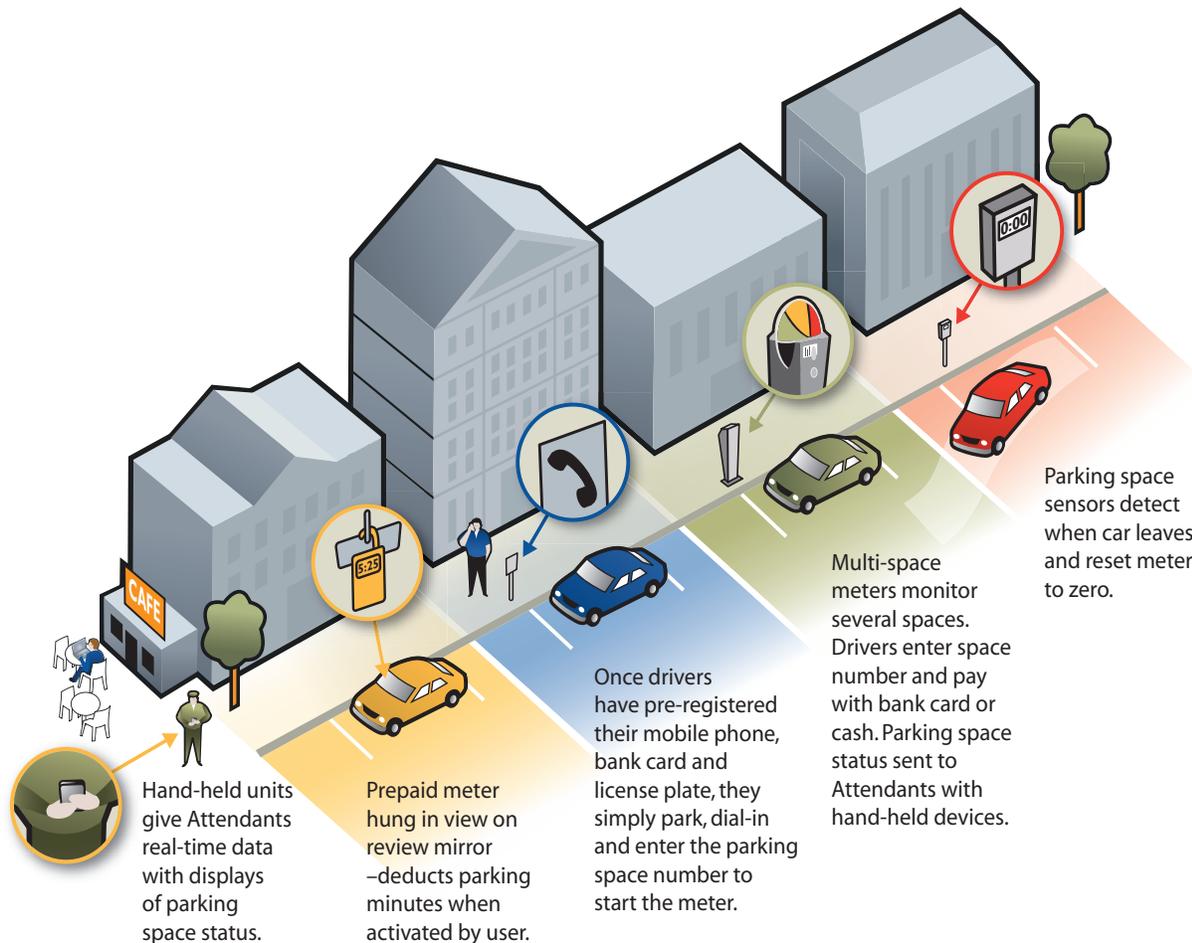


Building Inclusive Municipal Wireless Mesh Networks

The broadband wireless mesh network enables a municipality to automate and network-enable many unattended processes or services that would otherwise require inefficient onsite manual inspection. These can yield significant ongoing operating expense savings and enable the redeployment of personnel to more visible city services:

- **Smart parking metering and enforcement** — wireless-enabled parking meters, as shown in Figure 4, allow users to pay electronically (via credit card, debit card, or cell phone) and communicate expirations to a centralized control facility, which can dispatch nearby enforcement officers to ticket overdue spaces. Electronic payment minimizes the need for costly and risky collection of coin payments.
- **Automated utility metering and control** — wireless-enabled utility meters eliminate the need for manual meter reading and enable remote control (turn on and shutoff) of electricity, water, and other municipally-owned utilities. Connectivity for automated metering can be sold to privately-operated utilities. The health of metering systems can be remotely monitored to enable timely maintenance and replacement of deteriorating equipment. Automated metering eliminates problems such as access issues (e.g., meters behind locked gates) and employee health risks (e.g., traffic accidents, dog bites).
- **Mobile asset tracking and automated vehicle location (AVL)** — the municipality can monitor and track the location of its fleet vehicles and other mobile assets, ensuring compliance with schedules, aiding in real-time redeployment of resources in response to emergencies, and providing reliable arrival estimates to scheduled appointments.
- **Public transportation automation** — traffic monitoring and wireless smart signage can be used to communicate vehicle arrival and schedule information to commuters and visitors at public transportation stations.
- **Traffic light control** — traffic signaling systems can be remotely monitored and controlled.

Figure 4: Wireless mesh networks support applications that help automate municipal administration of parking metering and enforcement



Public Safety Applications

The third critical application set that broadband wireless networks can support is public safety applications running over Wi-Fi and/or the 4.9 GHz public safety band. These include mobile applications for police officers, firefighters, emergency medical technicians, and other public safety workers using wireless-equipped laptops and handhelds in their vehicles or on their person, as shown in Figure 5.

Video surveillance and real-time video sharing from both mobile cameras (e.g., dash-mounted cameras in police cruisers) and fixed-position cameras (both permanently installed on buildings or utility poles and set up ad-hoc at an incident scene) is also an important emerging use of broadband wireless for public safety.

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Figure 5: A wireless mesh Public Safety Network provides inter-agency communications, allowing police, fire and medical personnel to access and share voice, video and data for a coordinated response to an incident



These applications and their requirements are laid out in more detail in the BelAir Networks white paper, “Wireless Mesh Networks for Public Safety”.

Municipalities should recognize that support for public safety applications is a critical component to help maximize the use of the municipal wireless network, to attract funding from national and regional resources designated for homeland security purposes, and to buttress the political and business case for deploying the network.

Choosing the Right Wireless Network

These emerging new applications for municipal public access, public works, and public safety will place stringent demands on the wireless network: for more radio-frequency options, greater scalability to deliver huge amounts of low-cost bandwidth, seamless mobile connectivity for employees on foot and in moving vehicles, outdoor installation versatility, carrier-class reliability, deterministic network performance, and network security, as summarized in Table I.

Table 1: Implications of Public Works and Public Access Applications for Municipal Wireless Mesh Networks

PUBLIC ACCESS / PUBLIC WORKS ISSUE	IMPLICATIONS FOR WIRELESS NETWORK	TECHNICAL REQUIREMENT
Growing set of municipal employee and public Internet access applications	Network must deliver adequate bandwidth to steadily growing user population with growing bandwidth appetite	Network capable of collecting and delivering adequate bandwidth (potentially 1 to 2 Mbps per camera and viewer), plus aggregate backbone capacity to support all endpoints
Constant movement of municipal employees, citizens, and visitors, in vehicles and on foot	Network must support roaming with seamless mobility to maintain persistent connections with mobile users	Handoff between wireless network nodes of under 50 ms
Broad geographic distribution of public access users and mobile municipal employees	Network must cost-effectively scale to metropolitan-area and rural geographies; equipment must be installable in a range of public infrastructure settings	Mesh wireless to reduce requirement for wireline backhaul; equipment installable on utility poles, rooftops, exterior building walls, trees, cable infrastructure, etc.
Steep growth in use of high-bandwidth, delay-sensitive video, data and voice applications	Network must deliver huge amounts of bandwidth with low, predictable latency and jitter	Mix of single- and multi-radio nodes and switched mesh for capacity; traffic classification for quality of service for voice and video
Business-critical nature of public works applications, expectations of citizenry for reliable public access	Network must exhibit extremely high, carrier-grade network reliability and resilience	High hardware MTBF, automatic routing around failures, battery backup
Value of ad hoc networks to support municipal employees in disaster scenarios	Wireless equipment must facilitate simple, rapid deployment of ad hoc wireless networks	Flexible power sourcing; auto-configuration features; portable, rugged, weather-resistant hardware
Budgetary constraints on capital and operating expenses	Network must deliver cost-effective bandwidth and low cost of operation	Mesh to minimize backhaul costs; ease of installation and maintenance features
Sensitivity of public works communications; need to protect citizens from external network security threats	Network must be secure from outside tampering and eavesdropping	Security features for authentication, encryption, and network virtualization: 802.1x, Web authentication, WEP, WPA & WPA2, etc.
Need to minimize in-building wireless coverage costs	Outdoor network must reach into buildings (e.g., government offices, commercial building, schools)	Strong wireless node performance (transmit power and receiver sensitivity) to enable outside-in coverage to most buildings; complementary CPE to improve wireless coverage in homes, dense commercial buildings, and rural areas
Need for complete solution	Proven interoperability with laptop wireless cards, mobile routers, residential customer premise equipment (CPE), third-party billing, roaming, and subscriber management systems, and other complementary technologies	Documented performance testing of network's interoperability with relevant third-party equipment

Municipal Business Models

Municipalities have multiple options for how they fund and operate a broadband wireless mesh network. In an ongoing shift from early deployments in which the city operated the wireless network, a growing number of municipalities are concluding that they do not have the mission focus, business acumen, or technical expertise to operate the wireless network effectively.

Many current municipal wireless network projects are predicated on the use of a third party operator – a local telecom carrier, utility company, or wireless ISP – to oversee the design, installation, and ongoing operation of the wireless network on their behalf. A few cities may retain ownership of the wireless infrastructure and even manage its usage for public works and public safety applications, and wholesale bandwidth to a third-party operator who will manage and bill the public access portion of the network.

Funding of the initial capital and ongoing operating expenses of the network can be drawn from a variety of public and private resources, including:

- **Public/private partnership, with municipality as anchor tenant** — the third-party operator assumes ownership of the network with a fixed long-term revenue commitment from the city for public works and public safety application connectivity. The operator may then sell additional services like public access to businesses, residents, and visitors, with or without a revenue-sharing agreement with the city.



An example is the city of Minneapolis, which offered itself as the anchor tenant on a new municipal wireless network built and operated by wireless operator US Internet. The city agreed to a ten-year contract to buy all its municipal data and voice services from US Internet, including public safety, public works, public access for digital inclusion, and public school Internet connectivity, amounting to nearly \$3 million per year. The efficiencies of the wireless network allowed US Internet to significantly reduce the city's recurring costs for networking services while getting an assured return on its investment. The city not only saved money on its networking costs, but did not have to spend any tax dollars for the construction of the network.

- **Funding from external public grants** — national and state grant monies are tapped to help fund the wireless network. A common example is US Department of Homeland Security grants which are available for public safety improvements, e.g., deployment of video surveillance of crime hot spots and public transportation systems via the wireless network.
- **Fee-based public access** — residents, business, and visitors pay for public Internet access on an hourly, daily, or monthly basis. Schools and residences under digital inclusion initiatives may receive complete or partial exemptions from these charges.
- **Advertising** — can provide supplementary revenues to help support a public access network. Users may be exposed to ads when they connect, on a periodic basis throughout their session, with location-sensitive ads as they move about the city, and as part of entertainment or promotional video and data content shown on displays in public kiosks, public building elevators and lobbies, and in public transportation vehicles and stations.
- **Public funding** — the municipal network is viewed as public amenity and service delivery mechanism for the common benefit, much like public transportation, parks, and recreational facilities, and is funded entirely or in part by tax revenues.

Most municipalities are likely to rely on some combination of these funding options for their broadband wireless network. The public/private partnership option is emerging as a compelling solution for many cities, as it places the burden of initial infrastructure costs on the network provider. The partnership model enables the service provider to operate the network on a self-sustaining, profitable basis long-term while still meeting the municipality's strategic goals and reducing its overall networking costs.

Conclusion

Wireless broadband mesh networks provide a compelling means for municipalities to address a diverse range of requirements: affording new economic opportunities to citizens whose needs have been underserved by commercial Internet access services; improving public education and increasing parental involvement in student's lives; spurring economic growth; streamlining the delivery of municipal services; improving overall public safety; and reducing a broad range of operating costs like network bandwidth and asset management.

Municipalities must look beyond the ability of ubiquitous wireless Internet access to address digital inclusion and economic development initiatives. These worthy goals must be complemented by the use of the wireless network to support a broader array of public works and public safety applications. Planners must consider the likelihood that success in one area of the network will attract many new constituencies to it, placing steady upward press on bandwidth, reliability, and network performance. Modest data requirements today will soon be swollen by a flood of broadband data and video traffic. An increasingly mobile municipal workforce and citizenry will require a network that accommodates mobile users. The growing array of wireless-enabled applications will drive demand on the wireless network for proven end-to-end interoperability with a broad range of adjacent technologies.

Building Inclusive Municipal Wireless Mesh Networks

BelAir Networks builds mobile broadband multi-service mesh networks for municipalities with several critical, industry-leading advantages:

- Lowest total cost of ownership and fastest return on investment
- Broadest and most flexible product portfolio
- Best wireless network performance as measured in both laboratory tests and in live deployments
- Best municipal-scale wireless network coverage at lower nodal density
- Best capacity scaling
- Lowest, most predictable latency for delay-sensitive applications
- Highest reliability
- Broadest support for public access, public works, and public safety applications, including data, voice, and real-time video over Wi-Fi, WiMAX, and 4.9 GHz public safety bands

About BelAir Networks

BelAir Networks is the first company to offer scalable, wide-area Wi-Fi solutions with the highest quality for data, voice and video. BelAir's wireless networking solutions are built on the only multi-service architecture for wide-area wireless broadband deployments of Wi-Fi, WiMAX, and 3G Cellular networks. Built specifically for outdoor deployments, BelAir Networks patent pending solution delivers the lowest cost per user and deploys in days, blending into the physical infrastructure of downtown business districts, hotels and resorts, and college campuses. Founded in 2001, BelAir Networks is a privately held company headquartered in Kanata, Ontario.

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