

# Carrier Class — The Essential Ingredient for Successful Metro Wi-Fi

## Synopsis

*Recent well-publicized failures of a few Metro Wi-Fi initiatives have highlighted the challenges to getting the model just right. In addition to the partnerships among providers of deployment assets, operating expertise, radio planning, “anchor tenants”, and capital, as well as the mix of appropriately valued applications, technology choice can have a make-or-break impact on the up-front and ongoing costs of these networks.*

*This paper examines a range of technology options for wireless broadband in the municipal setting, looking critically at the key metrics of installed and operating costs per unit of coverage and capacity. We show that dramatic improvements in the economics and service performance of Metro Wi-Fi are possible when it is considered an extension of a telco-grade multi-service access architecture, rather than a scratch-built and separate network that ignores broadband assets already in place.*

## A Metro Wi-Fi Refresher Course

Rarely has a new technology trend been publicly judged as rapidly and emotionally as the earliest municipal based Wi-Fi projects.

Beginning in 2005, the prospect of using newly available solutions to provide broadband economically over wide-areas using Wi-Fi was developing quickly. Targeted at municipalities, Wi-Fi was positioned as an economical solution able to solve the previously unfeasible prospect of providing “border-to-border broadband coverage” for all of its residents and businesses. An entire ecosystem of supporters quickly developed and aggressively pursued the deployment of Wi-Fi networks.

Philadelphia, PA bolstered Wi-Fi’s momentum. As the first major city to pursue a network, Philadelphia sparked many other tier-1 cities to pursue major deployments and also opened the opportunity to communications service providers by selecting EarthLink to own and operate the network through an extensively structured services agreement which exchanged city-owned mounting assets for services.

By mid-2006 hundreds of municipalities had stated their intent to become “Wi-Fi Cities”. The business models cities could consider had expanded in many directions to include municipal ownership, community funded ownership, and competitive and incumbent service providers. This expansion continued to fuel aggressive pursuit of new initiatives.

As the initial networks were deployed, mixed technical success became a concern for all involved. User experiences similar to that of the earliest cellular networks spawned complaints of poor bandwidth and unreliable network coverage.

Users complained that simple connectivity was unpredictable, performance levels were sub-par and inconsistent across the coverage area, and network reliability was below that of other wireless technologies.

These complaints were subsequently quantified by numerous outside parties, quickly leading to judgments that Wi-Fi as an access technology was “not up to the task” in this application.

## Examining the Network Architecture

Because most available products and solutions are based on mesh technologies, current network architectures vary little. Most employ a comparable technical model:

- ▶ City-owned or managed mounting assets, most commonly street lights, used for access radio locations.
- ▶ Mounting locations chosen based on the availability of un-switched AC power, considered a requirement for the radio systems.

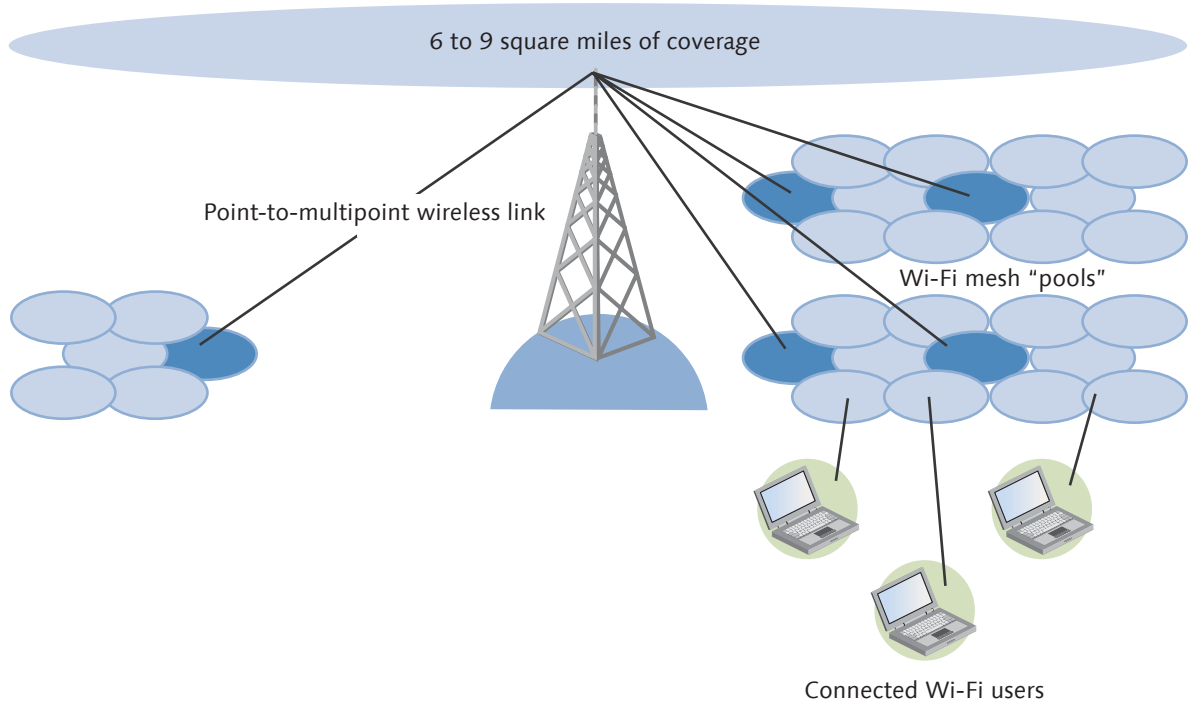


Figure 1: Muni Wi-Fi Reference Architecture

- ▶ Network capacity is distributed to “gateway nodes” located throughout the network via unlicensed point-to-multipoint wireless systems.
- ▶ Wi-Fi mesh radio systems are used to further distribute capacity through the network and also serve user access using ordinary 802.11 b/g Wi-Fi.
- ▶ A single Wi-Fi radio to simultaneously distribute capacity and serve users.

While simple to pursue logistically, this deployment model ultimately leads to a poor user experience. Further experience has also shown that it is both capitially and operationally impractical. In hindsight, it’s easy to critique most of these networks for similar issues:

- ▶ Architecture underserved the overall network by only distributing 6–10 Mb/s of bandwidth to each gateway node, resulting in potentially hundreds of end-user devices contending for this small amount of network capacity.
- ▶ By utilizing the same radio frequency to distribute network capacity and serve users, this architecture aggravates performance by magnifying Wi-Fi’s CSMA/CD foundation, turning the networks into large collision domains.
- ▶ Localized RF interference was largely ignored, leading to inconsistent network availability and performance. This issue was typically solved via deployment of an ever increasing quantity of radios.
- ▶ Radios were placed in less than optimal locations to serve users due to lack of choice in appropriate mounting locations. The model forcibly ignored mounting assets which could have been made available to the network operator if more powering choices were available and more time was allotted to determine optimal locations.

## Network Usability – The User Experience

The shortcomings of this network architecture yielded a set of material usability problems.

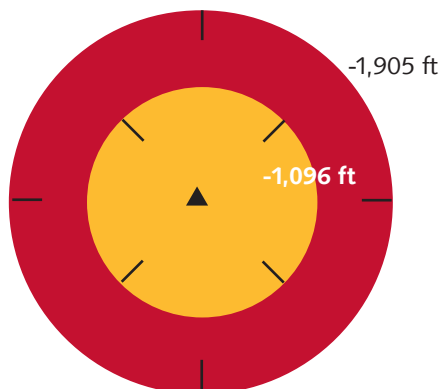
Data rates experienced by users were commonly below what is considered “broadband”, even when compared to other wireless technologies; often in the range of 100–500 kbps. Both commercial and municipal applications of these networks failed to perform to expectations due to inadequate bandwidth.

Further, network latency was often well beyond the sensitivities required for real-time multimedia applications (voice, gaming, video) due to the multiple wireless “hops” required to transport user traffic back to a wired network gateway.

Poor network coverage (*RF/radio availability*) also contributed to usability complaints in most networks. Often compounded by expectations which were unfairly set (95% coverage) by network planners—most networks were deployed using “off-the-shelf” indoor Wi-Fi access point (AP) technology, albeit often at a higher radio output power.

These rudimentary systems, combined with less than optimal mounting locations, provide a sub par user experience. This has led to a better understanding of the shortcomings of classic AP technology in metro environments, including the basic rule that more power does not equal better coverage. In fact, it creates issues which make the network less reliable and usable:

- ▶ Simply applying more power (without appropriate multi-antenna signal processing) creates a path imbalance between the access radio and the end-device.
- ▶ The high-powered AP radio can send a strong signal much farther than typical end-devices can transmit back.



Customers in the "red" zone would attempt to connect but would not be powerful enough.

Some laptops will incorrectly reduce their output power due to a high received power

**Figure 2:** Path imbalance diagram

- ▶ Consumer battery-powered devices, including most laptops, have very low powered Wi-Fi radios embedded. They often include software which reduces their output power further when a strong AP signal is detected.
- ▶ In metro environments end-devices often falsely reduce their radio output power because they sense a "strong" signal from an overpowered AP node.
- ▶ This situation aggravates the problem, causing the end-user device to function very poorly.

## Business Model Breakdowns

Compounding their clear technical limitations, many of the early Metro Wi-Fi networks suffered equally from unsuccessful business models.

The combination of urgency and lack of proper due-diligence of many projects resulted in failure. Many networks were planned with limited uses or applications in-mind and overlooked greater usage opportunities. Lack of business due-diligence and a "land grab effect" also led to partnerships with faulty economic and financial underpinnings. While difficult to quantify, these commercial failures equally impacted the reputation of Metro Wi-Fi networks.

## Summary: Metro Wi-Fi — What Happened!?

In summary, the short history led to a troubled start for Metro Wi-Fi networks. Fundamentally, the following causes and effects took hold:

### Limited Technology Choices

- ▶ Solutions were based on "off-the-shelf" AP technology
- ▶ Solutions relied heavily on mesh technologies
- ▶ Solutions weren't engineered for high service reliability

### Challenged Network Architectures

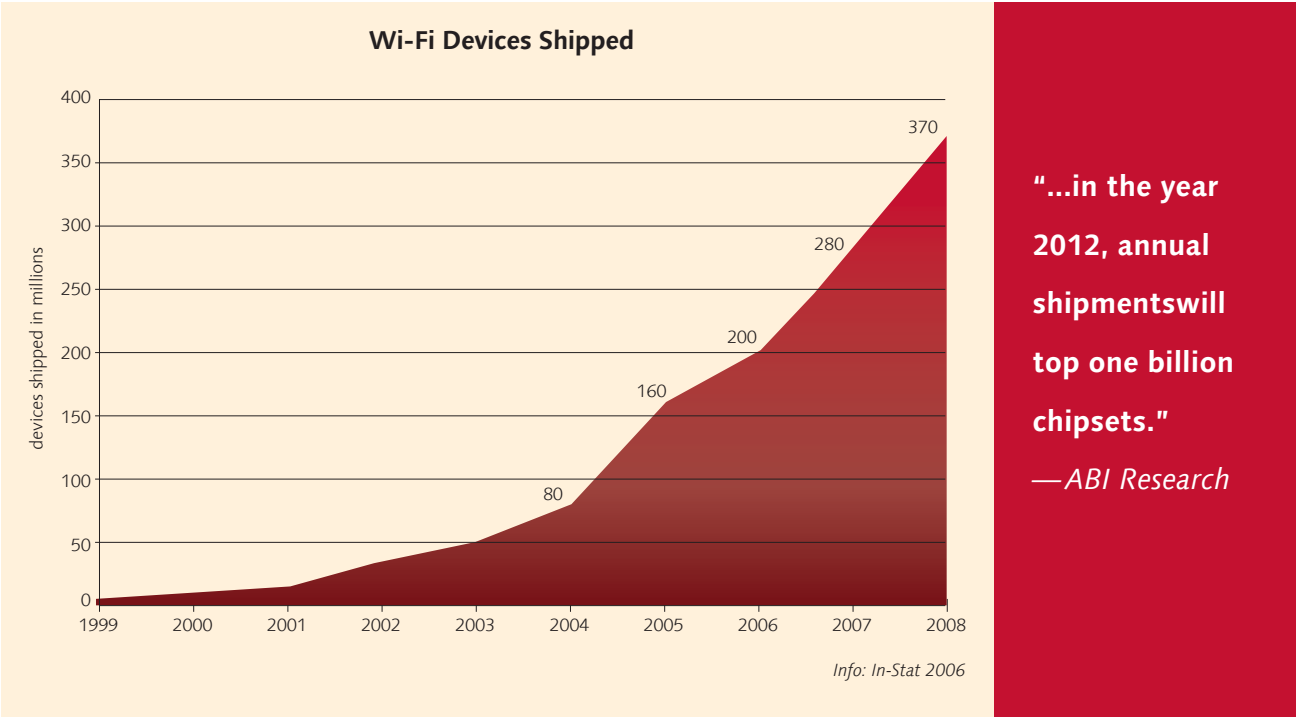
- ▶ Frequently used Point-to-Multipoint Wireless to inject capacity
- ▶ Over reliance on mesh technology reduced available bandwidth unnecessarily
- ▶ Relied on a single radio design to distribute bandwidth and serve users
- ▶ Undeveloped tools to deal with RF interference
- ▶ Radio locations dictated by municipal control and power availability

### Expectations were poorly set

- ▶ Early deployments meant many underappreciated nuances of networks
- ▶ Incomplete understanding of network uses

### Challenged Business Model Elements

- ▶ Rushed or ill-conceived plans
- ▶ One-dimensional network use
- ▶ Poorly capitalized owner/operator selections
- ▶ High capital and operational costs



**"...in the year 2012, annual shipments will top one billion chipsets."**

—ABI Research

Figure 3: Growth of Wi-Fi metrics

## Metro Wi-Fi 2.0

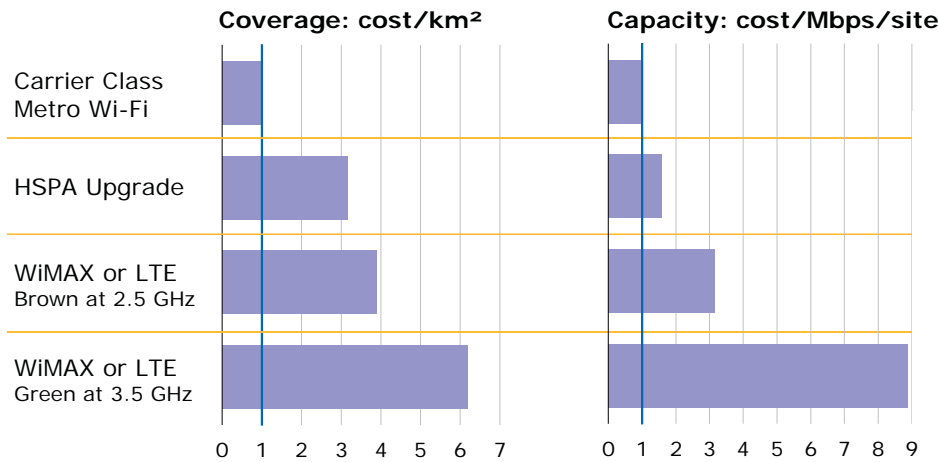
These early experiences with Metro Wi-Fi beg the question: Does Wi-Fi make sense as an outdoor, wide-area access medium? Without a doubt, the answer to this question is, *yes*.

At its foundation, Wi-Fi offers unmatched technical and economic attributes:

- ▶ Adoption is ubiquitous and growing. Nearly one billion devices are Wi-Fi enabled today, and projections call for accelerated adoption by device manufacturers.
- ▶ Wi-Fi operates in unlicensed spectrum, allowing properly engineered networks to be owned and operated by any party without costly licenses.

- ▶ Wi-Fi is becoming more capable. Operations in the licensed 4.9 public-safety band for varied applications makes Wi-Fi a uniquely flexible broadband wireless technology.
- ▶ *Wi-Fi resembles Ethernet* in its maturation. Wi-Fi is gaining speed, security, and capability as its application grows from local area to wide area.

## Relative Unit Costs



Sources: Intel, ArrayComm, WiMAX Forum, Qualcomm, Zhone analysis

**Figure 4:** Comparison of relative unit costs of coverage and capacity for broadband wireless alternatives.

## Economics vs. Other Broadband Choices

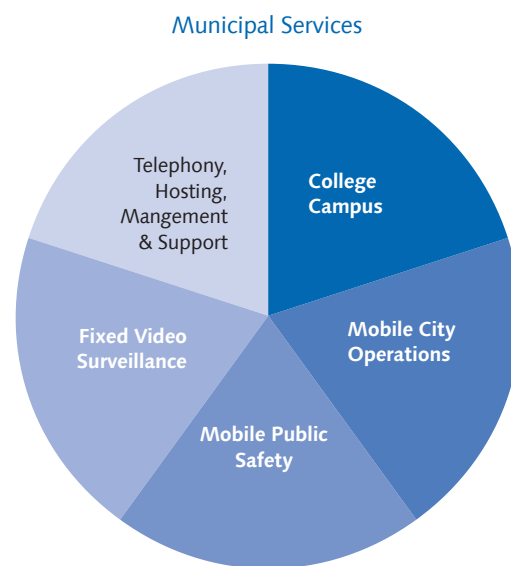
Wi-Fi offers much higher cost efficiency for delivering wireless broadband capacity, by a wide margin, than common alternatives. Wi-Fi is more cost effective both in terms of initial capital outlay per unit of coverage and cost per Mbps of capacity, a key metric for ongoing operation costs (see figure 4). For more details on these cost comparisons and a look at air interface engineering realities, see Zhone’s companion white paper *Clearing the Air on Broadband Wireless Economics*.

## Maturity of Metro Wi-Fi Business Models

The early challenges of Metro Wi-Fi have served a useful purpose in helping to illustrate which business models can be successful for municipalities or commercial service providers.

New networks should carefully consider the full suite of potential uses of the network (see figure 5). The collective municipal and consumer services are often sufficient to justify the expenditures of the networks provided adequate performance is available to serve each application.

Equally, the applications which are suitably enabled by Wi-Fi are growing extensively. Anchored by classic wireless broadband services, an exhaustive list of municipal government and public safety uses provide a solid foundation of ROI enhancing services.



**Figure 5:** Successful Metro Wi-Fi networks support a number of applications

## **Broadband Services**

- › Consumer Residential
- › Day-Pass and Visitors
- › Business and Municipal
- › Mobile Content Delivery
- › Social Inclusion

## **Advertising**

- › Local Business
- › Location-based Targeted Advertising

## **Municipal Government**

- › Building Inspection
- › Meter Reading
- › Asset Management
- › Traffic Management
- › Fleet Management
- › Case Management

## **Public Safety**

- › Video Surveillance
- › Mobile Law Enforcement
- › First Responder Interoperability

## **4.9 GHz Public Safety**

After September 11th, governments at all levels in the United States set about improving communications between emergency workers.

The FCC limited access to the 4.940 to 4.990 GHz spectrum to address the needs of public safety agencies and other public and private entities that provide safety services. Operating Wi-Fi in this frequency

allows for virtually interference-free, mission-critical communications using a licensed channel and enables public safety communications needs in three ways: Fixed wireless jurisdictional networks, incident response with fixed and mobile hotspots, and wireless video surveillance.

Examples of advanced multimedia communications made possible with broadband wireless networking include online multi-agency collaboration and whiteboarding, around-the-clock video monitoring and surveillance, real-time video feeds from an incident scene, instant multimedia messaging, and Voice over IP (VoIP).

Rugged 4.9 GHz mobility routers are available to mount in virtually any moving vehicle or vessel, including police cruiser, fire truck, ambulance, boat and mobile command center.

## **Devices and Services**

Apple's iPhone and other mobile Wi-Fi enabled devices coming into the market will further boost demand for Metro Wi-Fi networks.

In Mountain View, CA—the Metro Wi-Fi network operated by Google sees roughly 850 iPhones connecting to the network every day. This demonstrates the aggressive use of Wi-Fi enabled devices when an adequate wireless broadband network is conveniently made available to users.

T-Mobile USA, the smallest of the four major operators, is already leveraging Wi-Fi, and could also be tied to citywide efforts. Recently it launched a service that allows people to switch between Wi-Fi and cellular for transporting voice traffic.

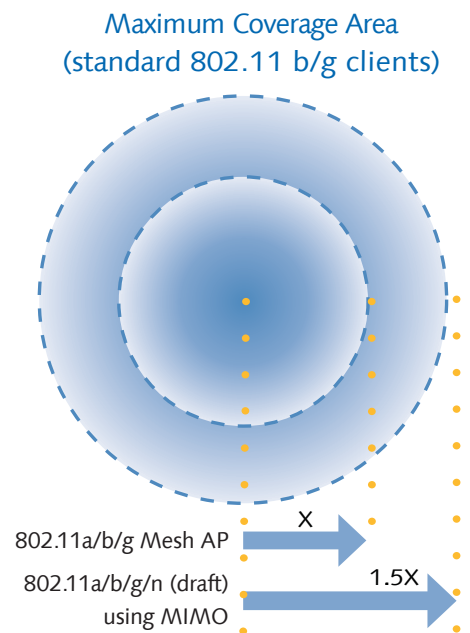


Figure 6

## Improving Technology

Fundamental to the changing Metro Wi-Fi landscape are the technical system improvements available to network operators. The next generation of Wi-Fi infrastructure does not suffer from the limitations of the prior generations and greatly increases the available network architectures. Notable technology improvements include:

### MIMO Antenna Technology

Multiple-Input and Multiple-Output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. MIMO technology offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Use of MIMO on the uplink is especially valuable, as it helps balance the downlink and uplink

range. On transmit, a MIMO-enabled AP is more power-efficient, prompting less power reduction by client devices. On receive, MIMO allows the AP to “listen” more carefully to the weaker client device, enhancing uplink range even further.

### 802.11n

Boasting greater speed and range, the 802.11n standard uses new technology and tweaks existing technologies to give Wi-Fi more speed and range. Independent reviews indicate that the claims of greater speed and range for 802.11n are true. Specifically, 802.11g products, which have a theoretical maximum throughput speed of 54Mbit/sec., typically provide real-world speeds of 22Mbit/sec. to 24Mbit/sec. In contrast, Intel says it’s seeing real-world speeds of 100Mbit/sec. to 140Mbit/sec. for 802.11n equipment.

### Improved Capacity Injection and Efficient Backhaul

Wi-Fi 2.0 substantially reduces dependence on costly and inefficient point-to-multipoint radios. Integrated DSL backhaul in a Metro Wi-Fi system can redefine the reference architectures used in Metro Wi-Fi networks. Network capacity is greatly improved and easily sized to the requirements of the users and applications, providing up to 100’s of megabits per second per square mile.

### Improved Reliability and System Robustness

Through techniques such as span line powering and strand mounting, telco-grade Wi-Fi solutions no longer require AC powering. This allows network planners to optimally locate access radios to anywhere local telephone lines are available—telephone poles, buildings, etc. Further, it improves system reliability and uptime to levels found in wireline telco services, a feature critically important to support for emergency and disaster response applications in the municipal context.

## Introducing Carrier Class Wi-Fi – SkyZhone™

SkyZhone is the industry's first Wi-Fi access system designed from the ground up to be Carrier-Class.

SkyZhone Wi-Fi enables a more reliable, lower latency, higher speed, lower cost network than comparable solutions. SkyZhone is line powered from the CO over a DSL line, the same copper pairs that provide power, also provide high speed backhaul. SkyZhone uses IEEE 802.3ah Ethernet in the First Mile (EFM) standard to provide over 20 Mbps backhaul per radio.

SkyZhone employs an innovative All-MIMO design which greatly improves coverage and interference management improving the connectivity success with today's widely varying consumer Wi-Fi devices. SkyZhone is offered in single and dual 802.11n access radio versions assuring the highest performance and compatibility with end devices.

Zhone products are installed in networks across the globe, providing the Zhone development and support team with extensive experience in the deployment of mission critical networks. This practical experience has been applied to SkyZhone, making it the industry's first outdoor Wi-Fi Access Point designed from the ground up to be carrier class.

The SkyZhone is the ideal product for public safety applications. Each SkyZhone is line powered, and is able to provide up to 22 Mbps of backhaul capacity. This solution delivers all the bandwidth needed for a video surveillance network. Further, SkyZhone provides an Ethernet port that also supplies 48Vdc, allowing an IP camera to be connected to, and powered by, SkyZhone.

Network management and provisioning is handled by the easy-to-use Zhone management system (ZMS), the same system used to manage over 10 million DSL and fiber broadband connections worldwide.



## Zhone's SLMS Architecture

SkyZhone is an integrated component in Zhone's Single Line Multi-Service (SLMS) architecture. SLMS incorporates a complete line of access, transport and CPE products that can be optimized to provide converged voice, data and video services across a carrier's entire serving area. Zhone's solutions allow carriers to consolidate legacy and future services onto a common environment and migrate these services to a unified packet infrastructure, managed by a common management platform. The result allows for current services to be maintained while adding new services and reducing the costs of the entire network. Zhone's Single Line Multi-Service architecture provides all that carriers need to support past, present, and future services.

**Features include:**

- Fully isolated public & City Government networks
- Secure Video Server location (Telco Central Office)
- Centralized battery backup
- 100% remotely powered high-definition cameras & Wi-Fi Access Points

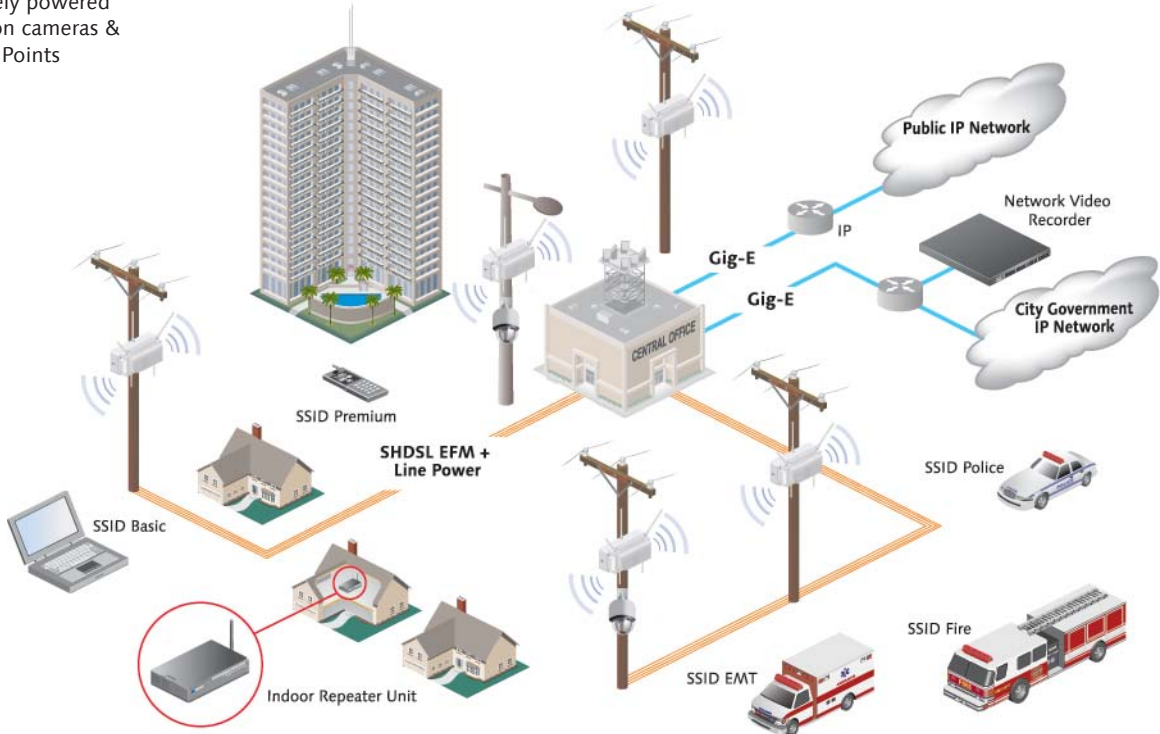


Figure 6: SkyZhone Solution Diagram

## SkyZhone Carrier-Class Wi-Fi — Why it's game changing

- **Support for true multi-service environments.** SkyZhone provides a uniquely scalable solution to address the combined requirements of municipal, public-safety, and consumer needs.
- **Support multimedia and bandwidth intensive applications.** With up to 22 Mbps of capacity per radio and low system latency—video, voice, and gaming applications perform to user expectations.
- **Superior network coverage.** SkyZhone’s all-MIMO antenna design produces exceptional user device connectivity at distances up to 100% greater than solutions using “off-the-shelf” AP technology.

- **Removes the limitations of multi-hop mesh.** SkyZhone’s integrated DSL backhaul provides network planners the tools necessary to distribute capacity logically through the network eliminating the halving effect and bandwidth contention issues common with multi-hop mesh systems.
- **Simplified network engineering.** Place access radios where the users are. SkyZhone’s integrated line powering allows network planners open consideration of mounting assets. If you can get a phone line to a location, you can power and provide service with SkyZhone.
- **Telco-grade reliability.** Public safety applications demand reliability. SkyZhone has been engineered to provide telco-grade uptime and line powering facilitates ongoing operation even during extended AC power outages.

- ▶ **Integrated network operations.** SkyZhone is fully integrated with Zhone's industry leading multi-service access platform and network management system, ZMS. Network operators can, for the first time, integrate Wi-Fi services into a larger, converged access network.
- ▶ **Improved service viability.** By expanding revenue opportunities to include a wide range of municipal, public-safety, and commercial applications — SkyZhone remedies many of the most poignant challenges of metro Wi-Fi.

## Summary

Aided by the latest technology innovations, SkyZhone has substantially raised the performance benchmark for multi-service metro Wi-Fi. Through its use of line powering, DSL backhaul, 802.11n, and all-MIMO antenna technology — SkyZhone allows service providers and municipalities to provide greater network coverage at higher bandwidth within a desired service area. Integrating Wi-Fi as part of a multi-service architecture extends the life of existing assets and enables network operators to profitably deliver a greater quantity of high value services with positive-ROI results. In addition to increased affordable backhaul capacity and greatly increased throughput, five nine's reliability and guaranteed uptime via central office battery and generator backup make true carrier-grade Wi-Fi a reality for the first time.

## About Zhone Technologies

Zhone Technologies, Inc. (NASDAQ: ZHNE) is a global leader in multi-service access network solutions, serving more than 700 of the world's most innovative network operators. The company offers the industry's broadest fully-integrated portfolio of MSAP, FTTx, EFM and Wi-Fi access technologies, enabling a full suite of services, including residential and business broadband, VoIP, and High-Definition IPTV. Zhone's converged multi-service access platform helps operators rapidly deploy premium services using copper, fiber, and wireless while improving network agility and reducing costs. [www.zhone.com](http://www.zhone.com)



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