

# Planning for enhanced indoor coverage and high capacity in WiMAX networks

Monica Paolini  
Senza Fili Consulting  
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Many WiMAX operators are at a crucial stage in planning or deploying WiMAX networks. Their wait to obtain the necessary spectrum licenses, to get the initial delivery of Mobile WiMAX products, or to select a vendor is either over or about to end. Finally they are ready to start rolling out their networks and test them in real-life environments, with paying subscribers, on loaded networks.

As operators have progressed through network planning or deployment, the hottest issues in the Radio Access Network (RAN) have become outdoor reach and indoor coverage. As subscribers start using their network, providing the high capacity density that new devices and applications require will be another key target.

These are recurring issues for all new wireless data technologies, as the underlying physics they need to overcome to get good coverage and capacity are the same. WiMAX is no exception, despite the fact that techniques like Orthogonal Frequency Division Multiple Access (OFDMA) and Multiple Input Multiple Output (MIMO) will enhance coverage and capacity.

In many ways, however, WiMAX network operators have to meet tough market requirements that

impose unprecedented challenges for coverage and capacity.

WiMAX and mobile broadband in general promise ubiquitous coverage, access for any fixed or mobile device, and support for bandwidth-intensive applications such as video and audio streaming or mobile TV. Subscribers expect WiMAX to combine Wi-Fi's data rates and GSM's extensive coverage. Being able to provide this type of service is a tall order for any WiMAX operator.

Market requirements for mobile broadband operators include the following:

- **Indoor usage.** In most cases, subscribers will access the network from indoor locations. This is the case both for fixed users (accessing the network from home or the office), and nomadic and mobile ones. Some WiMAX operators suggest that up to 80% of traffic is generated by indoor subscribers. Accustomed to cellular networks, subscribers will demand good indoor coverage and will expect that their WiMAX devices will work regardless of location.
- **Mobile devices.** With their smaller antennas and lower power, mobile devices typically use a bigger share of network resources than larger devices. This is especially true for indoor

locations, where mobile devices often need to use a less spectrally efficient modulation than fixed devices. As mobile devices become commercially available and subscribers start using them, requirements for network capacity will grow quickly.

- **High traffic levels from subscribers.** Subscribers will expect to pay a flat monthly fee and be able to access the WiMAX network as they do with their current work or home broadband connection. In some cases, WiMAX will in fact replace this connection. Even nomadic and mobile users will often be heavier users than current cellular data users, as they will have data-centric and consumer electronic devices (e.g. multimedia players or game consoles) that will typically run applications that generate heavy network traffic. Furthermore, these subscribers may even use the WiMAX network at home or in the office where they have an alternative wireline broadband connection, simply because it is more convenient.
- **Bandwidth-intensive applications.** Increasingly subscribers will use their devices for a wide range of broadband applications that for the first time will be accessible everywhere. Some of these (video streaming or music downloads) will require WiMAX operators to increase their network capacity. Uplink requirements will grow as well, as subscribers will generate the content (e.g. photographs, movies) they upload to their favorite websites.

Extensive outdoor and indoor coverage are not optional features. Once demand starts to grow, high capacity will also be a requirement. Ubiquitous coverage and high throughput are central to the expectations of potential WiMAX users across markets worldwide. It is crucial for operators to make the appropriate coverage and capacity assumptions early on in planning the network as this may lead to a more cost-effective and easily scalable network.

The question facing WiMAX operators today is how to meet these demanding market requirements in

a cost-effective, scalable way, adding infrastructure that is fully integrated within their currently deployed networks.

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## Why are indoor coverage and high capacity so difficult to provide?

The combination of high capacity requirements and extensive network access from indoor locations makes it a challenge to build a mobile broadband network.

This is not a challenge unique to WiMAX operators: Long Term Evolution (LTE) or Ultra Mobile Broadband (UMB) operators will have to face a very similar situation in due course.

Today's WiMAX networks rely on an outdoor infrastructure designed to provide Wide Area Network (WAN) coverage. They are typically optimized to provide wide coverage and range. Support for indoor coverage adds a significant burden to the existing network resources, as the penetration loss due to the first wall in a building usually ranges between 10 to 20 dB.

To extend the coverage range and improve indoor coverage, WiMAX changes its modulation scheme dynamically as a function of subscriber location. But there is a stiff price to pay: increased range and indoor reach results in lower throughput.

Devices located outdoors close to the Base Transceiver Station (BTS) will use the most efficient modulation scheme, Quadrature Amplitude Modulation (QAM), which has a higher spectral efficiency. However most of the subscribers are likely to be in indoor locations or towards the cell edge, where Quadrature Phase Shift Keying (QPSK) is used instead and has a lower spectral efficiency. The impact of modulation is substantial. When using QPSK 1/2 the data rate can be as little as 20% of the maximum throughput available with QAM 5/6 (Figure 1).

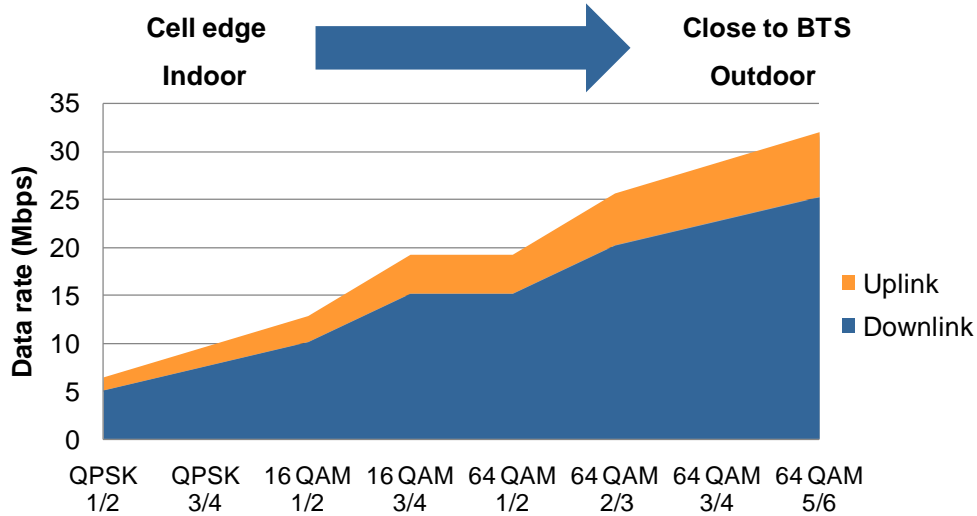


Figure 1. Impact of modulation on data rate in a WiMAX network, using IEEE 802.16e-2005, Time Division Duplex (TDD) duplexing and a 3:1 downlink to uplink ratio.

To make things worse, indoor subscribers are more likely to have longer sessions and to use more bandwidth-intensive applications, simply because indoor locations are more hospitable to data users. Over time, the higher number of users and mobile devices, coupled with the more extensive use of high-throughput applications, will further increase the overall need for capacity in the network, as mobile devices use network resources more heavily, because of their smaller antenna and more limited power.

Deep in-building coverage results in further penetration loss and the signal often does not reach these areas. WiMAX networks that provide indoor coverage are typically designed to reach only subscribers located past the first wall.

WiMAX networks will soon become capacity constrained and higher capacity density will be required due to the combination of high levels of indoor usage coupled with the increasing adoption of mobile devices, which typically cannot use the most efficient modulation in indoor locations, and with the increased per-user traffic levels.

A higher density of BTSs will be required to meet the requirements for both indoor coverage and capacity. The new cell sites added need to make

efficient use of spectrum and network resources and effectively have to pack more traffic capacity into the same area. To accomplish this, new network architectures are needed and BTSs will have to move closer to the indoor locations where subscribers are.

## The challenge for WiMAX operators

Demand for extensive indoor coverage and for high capacity density translates into a need for a high BTS density, with the number of BTSs increasing as more users sign up for services, using multiple devices and additional applications.

Deploying additional multi-sector, macro BTSs is often not feasible or cost effective. For operators it becomes progressively more difficult and expensive to accommodate a higher number of macrocells.

The equipment cost, although significant, is often not the major obstacle to denser macro deployments. Site acquisition, site preparation, and installation can have an even larger impact on the overall capex. This may make it impossible for operators that operate in areas with a high density of users to close their business case or it may unnecessarily delay profitability.

Furthermore, in many locations access to desired cell site locations can be difficult, expensive, or impossible to secure. Macrocells have to be installed on building rooftops or high towers: access rights to the existing infrastructure are often limited and creation of new cell sites requires a lengthy permission process, if allowed. The operator may be forced to rely on sub-optimal locations that may limit the capacity and coverage enhancements of the network expansion.

As the number of BTSs and traffic increases, operators also have to carefully monitor the growth of backhaul costs. If traffic from each BTS has to be transported by a wireline solution, opex costs may escalate quickly if each BTS has its own link. Depending on the location, the connection to the wireline infrastructure (perhaps DSL or fiber) may be expensive and may not be easily accessible from some locations (e.g. from lampposts). Conversely, wireless backhaul may cap operating backhaul costs significantly, as it then enables the operator to aggregate traffic efficiently and to skip the recurring backhaul fees associated with each deployed BTS, but may require additional spectrum and additional equipment investment. Furthermore, relay stations with integrated wireless backhaul support eliminate the need for the costly and lengthy process of preparing multiple sites for backhaul.

If expanding the existing infrastructure by increasing the density of base stations within the same architecture is not a viable—or at least cost-effective—option for most operators, they need to explore alternative architecture options that enable them make the best capacity-versus-coverage tradeoff, and to accelerate the path to profitability.

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## Moving beyond the macro BTS: alternative network architectures

In the initial stages a typical WiMAX deployment is driven by coverage. The highest priority for the operator is to ensure good outdoor coverage to

launch the service commercially. As demand and traffic grow, the network infrastructure rapidly becomes capacity-driven and additional BTSs have to be deployed in areas where coverage is already established.

While the introduction of mobility will further accelerate this process, we expect that capacity limitations will emerge in the short term with the introduction of desktop Customer Premises Equipment (CPE) used by indoor subscribers who use WiMAX as their fixed broadband connection and generate high traffic volumes.

In the early stages of most WiMAX deployments, a network architecture centered on multi-sector, macro BTSs prevails, as it effectively achieves good outdoor coverage with a limited number of BTSs.

However, a network architecture centered around macrocells often does not scale well when requirements for indoor coverage and high capacity become more pressing. The cost of hardware, site acquisition and preparation, and installation quickly outgrows the revenue opportunity, making it difficult to achieve a positive ROI.

To address the new coverage and capacity requirements, operators need to deploy more compact, smaller BTSs that support cost-effective backhaul solutions. They also come with less onerous site acquisition requirements and costs, as they can be installed in more accessible locations (lampposts, building walls), closer to street level, and they use less power. Because of their reduced size and weight, it is easier for the operators to gain access to cell site locations and to meet existing regulatory requirements.

The upcoming IEEE 802.16j standard will bring further support for integrated WiMAX wireless backhaul. It demonstrates industry commitment to providing a standard-based solution for more compact BTSs that relies on on-band wireless backhaul.

WiMAX operators have started to explore alternative network architectures, which can be

	Outdoor			Indoor	
	Macrocell	Microcell	Picocell	Picocell	Femtocell
<b>Sectors</b>	Usually 3	1-3	1	1	1
<b>Range (urban area)</b>	500-1,000 m	300-500 m	150-300 m	Indoor – Enterprise, public areas	Indoor – Residential
<b>Average sector capacity (10 MHz channel)</b>	10-15 Mbps	10-15 Mbps	10-20 Mbps	10-25 Mbps	10-25 Mbps
<b>Target cost</b>	High	Medium	Low	Low	Very low
<b>Site requirements</b>	High	Medium	Low	Low	None

Table 1. WiMAX BTS options

used to augment the initial macro infrastructure, and which are also increasingly used by cellular operators to boost capacity and indoor coverage. These options rely on different types of BTSs (Table 1) that form an underlay network that is used to extend indoor coverage and boost the capacity available to indoor subscribers. They are:

- **Microcells or picocells in outdoor locations**, in close proximity to the buildings they cover. Outdoor microcells and picocells are smaller and less expensive than macro, multi-sector BTSs, but they typically have a more limited range and, if they have a single sector, more limited capacity. They are typically used in urban areas with a high concentration of users and traffic. They are deployed in dense networks, where each cell covers a small area, ensuring good coverage and high capacity. They can be located on lampposts, rooftops, or on building walls. Microcells and picocells may use wireline or wireless backhaul. Mesh topologies may be adopted where wireless backhaul is fully integrated into the BTS.
- **Picocells in public indoor locations or within enterprise buildings**, to provide high density capacity and extensive in-building coverage. Indoor solutions are often the only way to provide deep in-building coverage. They are smaller than microcells and outdoor picocells, and their cost and ease of installation is even lower, as they can be mounted on walls or

ceilings. Picocells can use wireless or wireline backhaul, depending on the reliability and cost of the connectivity options available. Inexpensive wireline broadband links, where available, often prove to be the most cost-effective solutions. In buildings where wireline connectivity is not available to the operator or are overly expensive, wireless backhaul can be used instead.

- **Extension in residential and small business coverage with femtocells.** Self-installable, low-cost femtocells can be used to improve coverage in homes or small offices. They rely on the existing DSL or cable modem broadband connection for backhaul. The operator is usually not directly involved with the installation of femtocells. Subscribers typically purchase them in a store and install them at home or in the office.

Most operators have until now focused predominantly on a macro approach, but they are quickly moving to evaluate more flexible, cost-effective architectures based on smaller BTSs that can complement the existing macro infrastructure.

What is the best approach for a WiMAX operator? No single solution is capable of addressing the requirements of operators that are active in different physical environments and offer different services. The requirements of a WiMAX operator focusing on last-mile broadband connectivity fundamentally differ from those of a 3G mobile operator using WiMAX as an overlay network.

As a result, we expect to see individual operators selecting their own mix of different solutions that are deployed in specific areas within the WAN (e.g. indoor BTSs may coexist with outdoor microcells to provide a good balance of indoor and outdoor coverage).

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## Conclusions: the transition to enhanced indoor coverage and higher capacity

For the first time WiMAX operators face the challenge of deploying networks that provide reliable and consistent coverage both indoors and outdoors, coupled with the high capacity needed to support subscribers with mobile devices and high data requirements.

Increasingly WiMAX operators have started to look for solutions that address their stringent coverage and capacity requirements with a scalable, flexible and cost-effective network architecture.

The strategy that operators choose to enhance coverage and capacity will have a substantial impact on their network plans from the very beginning. As the initial network plan may facilitate or hinder future infrastructure expansion, it is crucial to start addressing the issues of indoor coverage and high capacity density during the early stages of network planning.

There is no single solution. Operators need to take a hard look at their market, and understand what the market requirements and specific challenges of their physical environment are. Most likely, each operator will find that a different solution is the best to get the coverage and capacity it will need in a cost-effective way.

The dominating trend, however, is towards a more diverse architecture that combines macro BTSs with smaller microcells, picocells, and femtocells, which brings higher capacity, better indoor

coverage and an overall more efficient use of spectrum. This will result in a higher density of BTSs that are deployed closer to where subscribers actually are, either in indoor or outdoor locations, and that are faster and easier to deploy in more accessible locations.

To date, vendors have focused on the macro infrastructure to ensure WAN coverage in initial WiMAX deployments. The next step is to develop more extensive product lines that will include high-capacity solutions for indoor and outdoor coverage and that will address the wide gamut of operator requirements.

There is no established path yet and a limited selection of products. But high capacity and enhanced coverage are issues whose importance is rapidly escalating, as demand for WiMAX services grows and mobile devices make their appearance in the market.

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## Acronyms

BTS	Base Transceiver Station
CPE	Customer Premises Equipment
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
OFDMA	Orthogonal Frequency Division Multiple Access
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RAN	Radio Access Network
RF	Radio Frequency
SoC	System on a Chip
TDD	Time Division Duplex
UMB	Ultra Mobile Broadband
WAN	Wide Area Network

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## About DesignArt Networks



DesignArt Networks Ltd. is a fabless semiconductor company driving the evolution of the 4G wireless network infrastructure, towards high-density, high-capacity deployments with ubiquitous and uniform out- and indoor coverage. DesignArt provides a comprehensive WiMAX System-on-a-Chip

(SoC) silicon platform, with the goal of substantially lowering the cost of the WiMAX network infrastructure. Based on DesignArt's patented single-chip design architecture, this SoC platform enables equipment vendors to build a portfolio of base and relay stations, ranging from micro, pico to femtocells and multi-service access point designs. DesignArt combines an experienced management team with strong technology leadership, and holds a unique combination of expertise and intellectual property. For more information about DesignArt Networks, please visit [www.designartnetworks.com](http://www.designartnetworks.com).

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## About Senza Fili Consulting



Senza Fili Consulting provides advisory support on wireless data technologies and services. Our expertise extends to cellular communications, WiMAX, Wi-Fi, and other fixed and mobile Broadband Wireless Access (BWA) technologies. We assist vendors in gaining a better understanding of the service provider and end-user markets. We work alongside service providers in developing a wireless data strategy and in assessing the demand for wireless services. Independent advice, a strong quantitative backing, and an international perspective are the hallmarks of our work.

At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, business plan support, due diligence, white paper preparation, training, and evaluation of end-user requirements. Our clients are international and span the entire value chain; they include fixed and mobile operators, ISPs, wireless ISPs, other service providers, vendors, solution providers, system integrators, investors, and industry associations.

For additional information you can visit us at [www.senzafiliconsulting.com](http://www.senzafiliconsulting.com), or you can contact us at [info@senzafiliconsulting.com](mailto:info@senzafiliconsulting.com) or at +1 425 657 4991.

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