Compact base stations: a new step in the evolution of base station design

Squeezing out cost, volume, and complexity from WiMAX deployments

- Compact base transceiver stations (BTSs) are the latest base station design to be introduced in the market. They bring WiMAX operators flexibility and cost savings while retaining the performance of macro BTSs.

- Compact BTSs can be installed in single-sector or multiple-sector configurations as alternatives to distributed BTSs with remote radio heads (RRHs).

- Unlike traditional macro BTSs, compact BTSs do not require ground shelters and cooling equipment. Yet they support high-performance features such as multiple antennas per sector with multiple input, multiple output (MIMO), and beamforming.

- With a smaller footprint, lighter weight and lower power consumption, compact BTSs cost less to install and to operate. Our analysis shows that operators can save 38% to 47% in capex and opex over a five-year period.

SENZA FILI CONSULTING

A new, more varied radio access network (RAN) topology is emerging, driven by the availability of new technologies, more demanding performance, coverage and cost requirements, and innovative business models. The traditional ground-based, multi-sector macro base transceiver station (BTS) is rapidly losing its dominant position to single-sector micro and pico BTSs with a smaller footprint, and to distributed multi-sector BTSs with remote radio heads (RRHs).

A new type of base station, the compact BTS, has also entered the market, further reducing footprint and power consumption, while retaining the performance of macro BTSs.

This paper introduces the concept and value proposition of WiMAX compact BTSs, compares compact BTSs to other base station form factors, and examines the total cost of ownership (TCO) for compact and distributed BTS configurations.

What is a compact BTS?
Single-box base station with radio frequency (RF) and baseband components in a fully integrated, ruggedized enclosure, mounted at the tower top, adjacent to the antenna array
Lightweight equipment with a small footprint
Software-defined, single system-on-a-chip (SoC) architecture
Support for multiple antennas and beamforming with a performance comparable to that of macro BTSs, but with lower power consumption
No ground equipment, shelter, or air conditioning needed
Only power and Ethernet (CAT-5 or fiber) cables required to operate the base station and connect it to the backhaul

Table 1. What is a compact BTS?

Why compact BTSs?

After a long wait punctuated by frustration about high costs and poor performance, the mass market has finally embraced wireless internet access, both for last-mile fixed broadband access and for mobile access. Devices like the iPhone and Android smartphones, netbooks, and other data-centric devices like the iPad or the Kindle enable subscribers to use their devices intensively for a growing set of applications.

Subscribers generate huge amounts of traffic (7 GB among Clearwire mobile subscribers in the US, and over 10 GB on average per month at Yota in Russia), and there is no sign that growth is slowing down. At the same time, average revenues per user (ARPUs) for combined voice and data are stable or declining, and unlikely to grow significantly in the mid-term future.

WiMAX and cellular operators are challenged to meet subscriber expectations at acceptable price points while retaining healthy profit margins. Operators are under constant pressure to keep costs down without lowering the service level. The RAN, the main contributor of capex and opex, is the main focus for cost reduction efforts. To contain deployment and operating costs, operators need equipment that delivers robust performance at a low cost per bit, and that can be installed quickly and cost effectively.

WiMAX has increased the need for a wider range of base station form factors, as it not only enables incumbent fixed and cellular operators to expand their network but also encourages greenfield operators—whether nationwide, regional or rural operators, vertical players, or municipalities—to enter the market with new business models. Deployment models based on macro BTSs often do not meet the cost/performance requirements of greenfield operators which are on a tighter budget or operate in low-density, underserved areas. Incumbent operators too have started to move away from ground-

based multi-sector macro BTS, and have shown a strong interest in new distributed macro BTS designs and in micro and pico BTSs, which can have either ground-based or a distributed design.

With a smaller footprint and lower power consumption, compact BTSs (Table 1) address the needs of WiMAX operators to deploy powerful and yet affordable equipment that meets the same throughput and coverage requirements of macro BTSs.

The evolution in base station architectures

The variety of base station form factors gives WiMAX operators an unprecedented flexibility in choosing the solution that best fits their needs (Figure 1). Table 2 presents the evolution in BTS architecture, and compares three options WiMAX operators can choose from:

traditional ground-based BTS, and more innovative distributed BTS and compact BTSs.

Heavy, power hungry and expensive **ground-based BTSs** are the most common in today's cellular networks. Ground-based macro BTSs deliver high-power transmission, leading to a higher downlink throughput and wider coverage area than other base station designs. But to achieve this performance, they require more power and hardware on the ground, which has to be housed in an environmentally-controlled enclosure.

The coaxial cables that connect the base station to the antenna can add several thousand dollars to the price tag of a cell site. They also result in power losses that either decrease performance or further increase the power consumption of the base station. To limit coaxial cable loss, the ground equipment has to be located as close as possible to the antenna location. This may increase rental site costs or it may simply not be feasible in locations other than cell towers that are designed to host this type of equipment.

	Ground-based BTS	Distributed BTS	Compact BTS
Configuration	Antenna on the tower, other components at the base	Antenna and radio on the tower, baseband at the base	Antenna and single-box BTS on tower
Number of sectors	Usually three in a macro BTS configuration	Usually three in a macro BTS configuration	Usually three in a macro BTS configuration
Site requirements	Cell towers, building roofs with room for ground equipment	Cell towers, building roofs with room for ground equipment	Any mounting asset
Air conditioning	Yes	Yes	No
Connection to ground equipment	Coaxial cables, power	Fiber cables, power	Single fiber or CAT-5 cable for backhaul, power
Weight	100 kg – 200 kg	30 kg – 145 kg	15 kg
Power consumption	335 W – 800 W*	300 W – 600 W*	65 W – 150 W

* Power consumption figures include only power consumption by the BTS and do not reflect electricity needed to power air-conditioning equipment

Table 2. Evolution in base station architectures

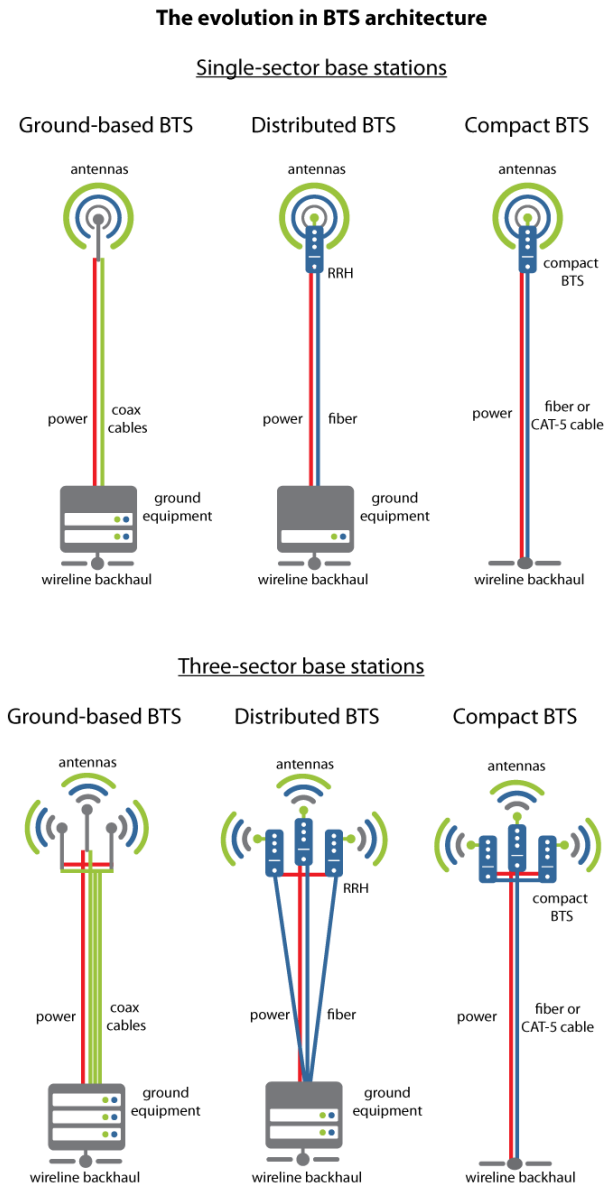

Figure 1. The evolution in BTS architecture

Pushed by operators, most WiMAX vendors have moved toward a more cost-effective **distributed BTS** architecture, with RF components mounted next to the antennas in RRH units to eliminate coaxial cable loss. In distributed BTSs, coaxial cables to the ground are eliminated in favor of optical fiber strands, giving operators more flexibility in locating the ground equipment.

With the adoption of distributed BTSs, installations on roof tops, building walls, and other non-telecom infrastructure have become more common. In the US, for instance, Clearwire prefers distributed BTSs because gaining access to existing cell towers is difficult in some areas, and other installation sites have typically lower rental costs. This is a common situation for greenfield operators that have to compete for tower space against incumbents, or that operate in markets where cell tower space is scarce.

Both ground-based and distributed BTSs usually have multiple sectors—typically three, with a frequency reuse of 1/3/3. Increasingly, WiMAX vendors are introducing smaller and lower-cost micro and pico BTSs that have only one sector. In some cases, operators start with a single-sector BTS and upgrade to multi-sector base stations as traffic grows.

Depending on the vendor and target market, micro and pico BTSs may have a ground-based or distributed architecture. Their installation requirements are in line with the respective macro BTS architecture—i.e., costs are higher for ground-based configurations, and lower for distributed one. In an effort to accommodate the performance and cost requirements of WiMAX operators, vendors now offer more choices among micro and pico BTSs. Micro BTSs are becoming popular as a way to provide wide area coverage in low-density, rural areas or to create high-capacity hot-zones in urban areas. Pico BTSs provide fill-in coverage for indoor and outdoor environments in high-density urban areas.

Compact BTSs are the latest entrants into the market (Table 1, Figure 2). They are designed to meet the demand for base stations that are cost effective to deploy and operate, that are fast and flexible to install, and that are suitable both for low-density rural areas and for high-traffic urban areas. Table 3 lists their key advantages for operators.

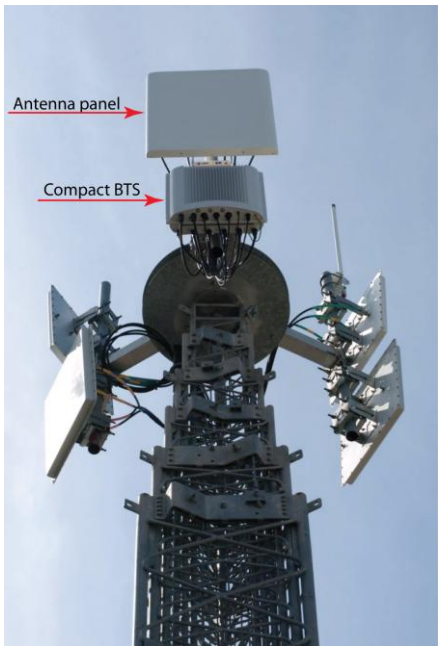

Figure 2. Compact BTS with a six-antenna array

Source: PureWave Networks

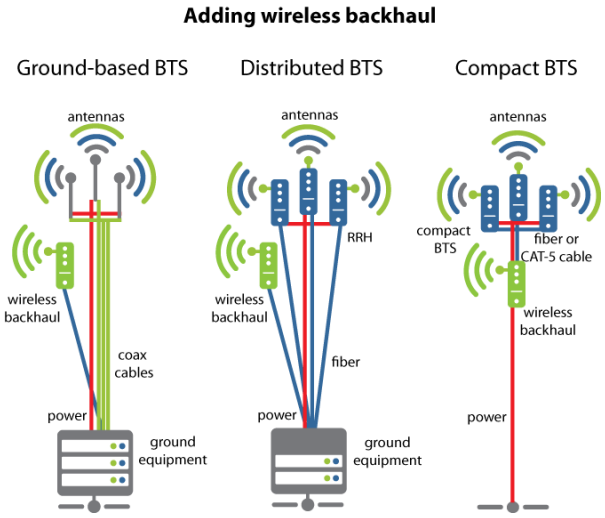

Figure 3. Adding wireless backhaul

In a single, ruggedized enclosure, compact BTSs combine RF and baseband components. They can be mounted on a cell tower, rooftop, or any location where power and backhaul are available. If wireline backhaul is used, a standard metro Ethernet switch may be required on the ground. If wireless backhaul is used, only power from the ground is required to connect the compact BTS, as a CAT-5 or fiber cable can directly connect the compact BTS to the wireless backhaul equipment on the tower (Figure 3).

Compact BTSs can be deployed as standalone units in single-sector configurations where capacity requirements are limited, such as rural areas with few subscribers concentrated within a restricted zone, or indoor locations and heavily-built urban areas where operators may use a hotspot deployment model with a high density of BTSs. In areas where the capacity and coverage of a multi-sector macro BTS are required, multiple compact BTSs can be combined in a multi-sector configuration to provide a comparable throughput over the same coverage area.

The view from the operators: Razzolink

Razzolink has been offering wireless broadband connectivity in rural areas in California since 2004 using 2.5 GHz spectrum, initially using pre-WiMAX macro BTSs with a shelter and cooling unit installed on the ground. Tower space availability, expensive equipment, and high energy costs all contribute to making the business case difficult for a rural operator. "Sometimes the energy costs for air conditioning are higher than those for the base stations," said Tony Iacopi, Razzolink EVP and co-founder of Razzolink.

Razzolink has now moved to compact BTSs as it upgrades to WiMAX to reduce its capex and opex associated with heavy ground and tower equipment. With compact BTSs and wireless backhaul, Razzolink has eliminated the need for indoor equipment.

Iacopi has been testing compact BTS equipment for the past two years and now has started to deploy compact BTSs on Razzolink's network. "We get better throughput and a wider coverage area, with a much smaller equipment footprint," Iacopi says. This will enable Razzolink to serve more customers with the same number of base stations—"more revenues, less costs," Iacopi summarizes.

The value proposition of compact BTSs
Same performance as a distributed BTS: ▪ Same throughput, coverage, and functionality as distributed BTSs with same number of sectors
Flexible configuration: ▪ Single-sector configuration with one compact BTS ▪ Multi-sector configuration with multiple compact BTSs at the same site
Lower capex, due to: ▪ Less expensive equipment ▪ No ground equipment required ▪ Lower installation costs
Lower opex, due to : ▪ Lower power consumption, no active cooling ▪ Lower rent, because of equipment's smaller footprint and of use of non-traditional sites with lower site rental costs
Faster time to market: ▪ Single-box, preconfigured equipment requiring less expertise and time to install ▪ Installation on existing infrastructure with reduced permitting requirements
Future-proof: ▪ SoC technology enabling software-defined radio functionality in a compact architecture
Green technology: ▪ Low power consumption, due to the absence of ground equipment and, especially, power-hungry cooling units ▪ Off-grid operation using solar or battery power

Table 3. The value proposition of compact BTSs

Are compact BTSs cost effective?

Some advantages of compact BTSs over base stations that require ground equipment transcend direct cost considerations. Some operators are relieved to deploy compact BTSs because, in many of their locations, ground equipment is not an option. For instance, Kansas Broadband Internet installs BTSs on grain elevators, where dust and fire hazards prevent the installation of ground equipment.

For most operators, cost is a central factor in choosing which BTS form factor to deploy and in selecting installation locations. To address this issue, we developed a TCO model that compares distributed and compact BTSs, and that looks at capex and opex over a five-year period. Only cost items that are affected by the choice of BTS architecture are included in the model. We left out of our comparison ground-based BTSs because they address a separate market segment than that covered by distributed and compact BTSs.

Cost items like backhaul or maintenance that do not change across solutions are also excluded from the analysis. As a result, our capex estimates cover BTSs and other equipment (i.e., ground shelters, cooling systems) along with installation costs (permitting included). Opex items include only rental and power costs. All capex costs are incurred during the first year. Opex increases at an annual rate of 2%. Cost assumptions are listed in Table 4.

We analyzed two base-station configurations: a single-sector cell site with a single distributed or compact BTS, and a three-sector BTS, with either a three-sector distributed BTS or three compact BTSs. All base station configurations use 2x2 multiple input, multiple output (MIMO). The single-sector configuration is best suited for rural areas with demand concentrated in small isolated areas, or in urban areas where the operator wants to establish a high-capacity coverage area with base stations

with omni-directional antennas. The three-sector configuration is the most commonly used in cellular networks and by WiMAX operators to maximize coverage from a single cell site.

Given the disparity in costs across operator type, location type, and region, we looked at two common scenarios—a large WiMAX operator serving densely populated areas and a rural WiMAX operator—to illustrate the relative impact of key cost drivers.

Although the capex and opex inputs vary across operators, the analysis still holds once the required changes in assumptions are made. In some cases, for instance, there may be an additional source of savings. This is the case in emerging markets where the power supply can be unreliable and operators use fuel-based power generators or, increasingly, solar panels, which increase costs and may impose additional siting requirements. A base station that requires less power allows operators to cut costs further, and to buy less powerful generators or smaller solar panels.

Large WiMAX operator scenario. In this scenario, the operator is an incumbent fixed or cellular operator, or a greenfield operator deploying a network mostly covering urban and suburban areas. These operators typically face higher site acquisition and rental costs, which are prevalent in urban and suburban areas, than rural operators. In some cases, large operators can keep costs down by leveraging their existing infrastructure and co-locating base stations with their installed equipment.

Cost savings over a five-year period for a large WiMAX operator using a compact BTS can reach $48,390 for a single-sector BTS (42% overall cost savings, derived from a 58% reduction in capex and a 32% reduction in opex) (Figure 4), and $68,220 for a three-sector BTS (38% overall cost savings, derived from a 48% reduction in capex and a 30% reduction in opex) (Figure 6).

The main sources of capex savings are in the BTS installation and purchase of non-base station equipment (i.e., cooling system and shelter); the main opex savings are in rent and power consumption.

	Distributed BTS		Compact BTS	
	One sector	Three sectors	One sector	Three sectors
Capex				
Base station (2x2 MIMO)	$18,000	$48,600	$9,500	$28,500
Permitting, planning, installation	$16,200 (large op) $13,000 (rural op)	$18,000 (large op) $14,400 (rural op)	$8,000 (large op) $6,400 (rural op)	$10,000 (large op) $8,000 (rural op)
Other hardware (enclosure, air conditioning)	$10,200	$12,000	$1,000	$2,000
Opex per year				
Rent	$11,800 (large op) $7,100 (rural op)	$16,800 (large op) $10,100 (rural op)	$9,400 (large op) $5,700 (rural op)	$11,800 (large op) $7,100 (rural op)
Power	$5,000	$7,200	$2,000	$5,000

Table 4. Capex and opex assumptions. Equipment prices are list prices, and exclude volume or other discounts. Where only one cost figure is listed, it is assumed to be the same for large and rural operators.
Source: WiMAX and cellular operators, vendors, Senza Fili Consulting

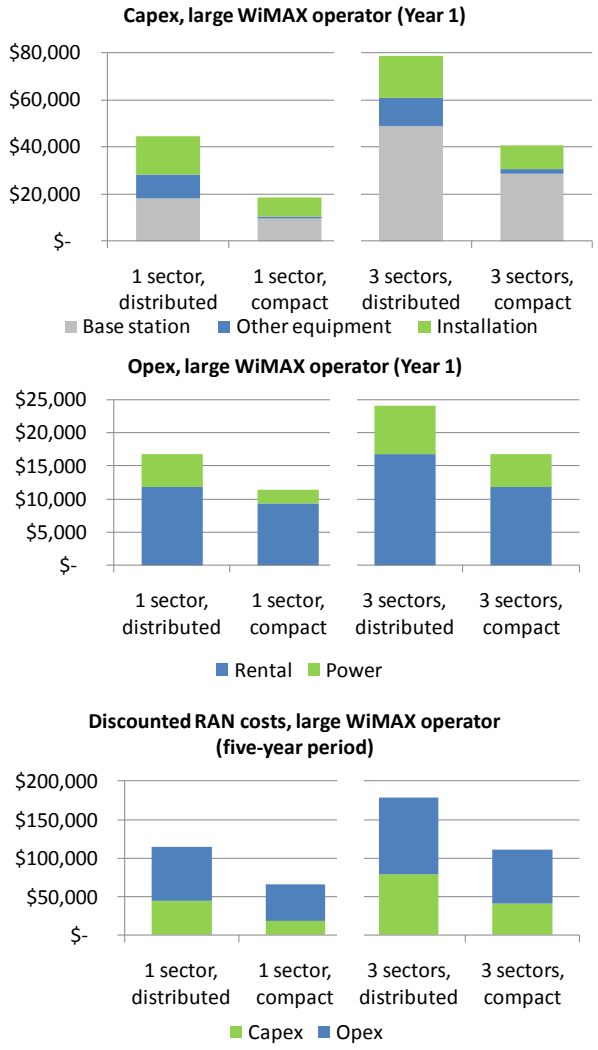

Figure 4. TCO analysis for a large WiMAX operator

Rural WiMAX operator scenario. Rural WiMAX operators are smaller operators that focus on low-density, underserved areas and typically have regional networks, ranging from a handful to a few hundred sectors. They mostly provide fixed broadband access to residential and business customers and, as a result, they have to be very cost sensitive to become or remain profitable. In some cases, they have access to low-cost locations, through their cooperation with local businesses, educational institutions, or municipalities. In other cases, access to a cell location can be obtained in exchange for broadband connectivity. These locations, however, are usually not on cell towers and some operators have strict limitations on what equipment they can deploy.

Although we compared the costs for compact BTSs to those for distributed BTSs, many rural operators find a distributed BTS solution to be too expensive. They are more likely to adopt lower-cost technologies that use license-exempt spectrum. Many rural operators recognize that WiMAX is the technology best suited for their needs, and the high costs of installation and equipment for macro BTSs have slowed down adoption. With compact BTSs, we expect rural operators to expand their use of WiMAX as a replacement for license-exempt technologies.

WiMAX brings operators another valuable advantage: low-cost, off-the-shelf customer premises equipment (CPE) and other subscriber devices from multiple vendors. In addition to reducing the subscriber device costs, the use of a standards-based technology such as WiMAX with proven interoperability frees the operator from dependence on vendors selling proprietary equipment and gives them a stronger negotiating position.

Rural operators have overall lower costs. On the capex side, we estimate installation costs to be 80% of those faced by large WiMAX operators, due to the fact that they operate in areas where there is less competition for mounting assets, real estate is cheaper, and permitting is easier. Equipment costs are approximately the same for the two types of operators because they need comparable products. However, while large operators benefit from more aggressive volume discounts, rural operators often choose to purchase equipment with limited functionality that costs less, or to select less-expensive vendors. When both these factors are taken into account, the equipment costs for large operators and rural operators are approximately the same.

Opex due to power consumption is similar for rural and large operators because the equipment is the same. Site rental, however, is on average cheaper for rural operators because they operate in lower-cost areas, and often install equipment on mounting assets that are less expensive than cellular towers.

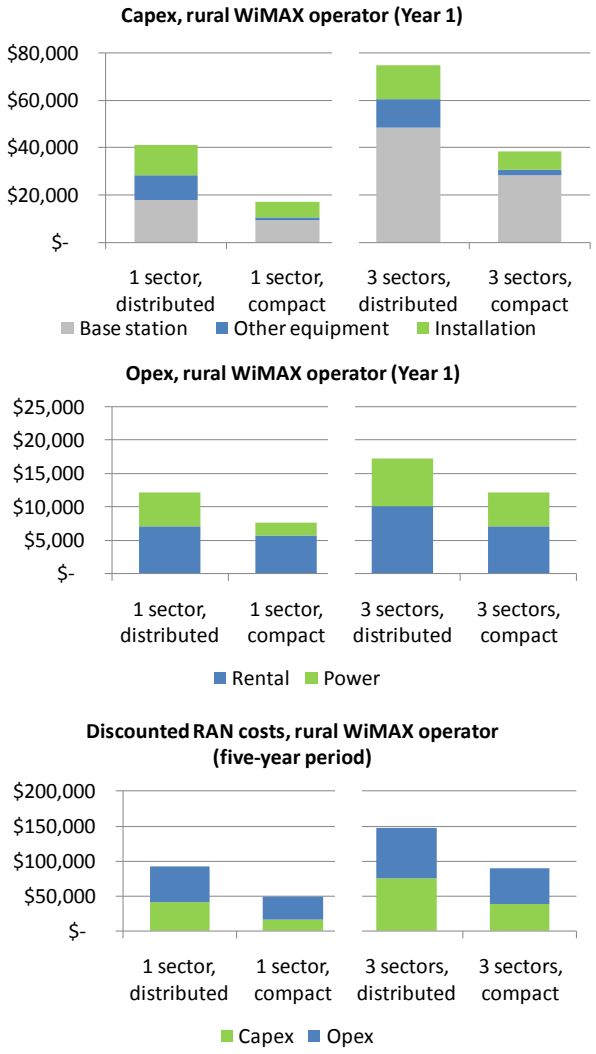

Figure 5. TCO analysis for a rural WiMAX operator

Rural operators can save $42,814 per site over five years (Figure 5) if they choose a single-sector compact BTS over a distributed BTS (47% overall cost savings, derived from a 59% reduction in capex and a 37% reduction in opex). They can save $58,187 for a three-sector BTS (40% overall cost savings, derived from a 49% reduction in capex and a 30% reduction in opex) (Figure 6).

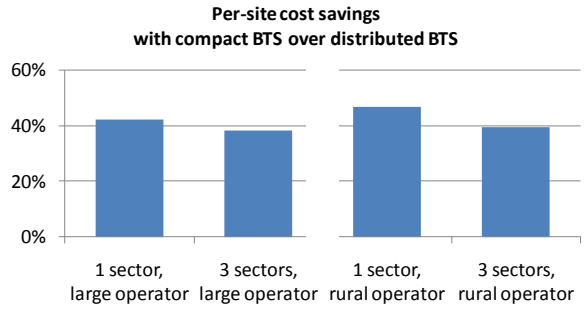

Figure 6. Per-site cost savings with a compact BTS cell site over a distributed BTS cell site

The view from the operators: Kansas Broadband Internet (KBI)

KBI is a rural operator covering 22 counties in Kansas. In the past, KBI relied solely on license-exempt spectrum. It is now widening its coverage area using 2.5 GHz spectrum with WiMAX compact BTSs. KBI gained access to the spectrum through innovative partnerships with educational institutions that will benefit from the WiMAX infrastructure, through discounted access for students, and from revenue share agreements with KBI.

It was the availability of compact BTSs that made it possible for KBI to switch to WiMAX. Lee Miller, KBI's President and CEO, explains that "installing ground equipment is simply not an option for us," as it would have raised costs too much (KBI does not own environmentally controlled shelters at existing cell sites) and restricted the choice of sites. Miller estimates that a ground equipment solution would require a 16- to 18-month payback period, which is not sustainable.

"Compact BTSs will allow us to grow more rapidly, leveraging our experience with license-exempt technologies for licensed spectrum deployments," Miller said. Compact WiMAX BTSs have a form factor similar to the proprietary equipment KBI is currently using, allowing the operator to retain its operations model while increasing cell range and throughput.

Conclusions

Compact BTSs introduce a needed form factor innovation to the market. They bring WiMAX operators more flexibility, lower costs, and reduced complexity, without compromising performance.

Operators are increasingly eager to move away from the traditional macro BTS model, and compact BTSs allow them to do so. Compact BTSs can be used in standalone mode as single-sector BTSs, or can be combined in a macro configuration that provides the same performance as a distributed macro BTS with the equivalent number of sectors.

Large operators stand to benefit from compact BTSs in dense, urban environments, where they have established coverage with a macro network but need to quickly add capacity, as they add more users and see higher traffic levels from existing subscribers. Smaller, regional WiMAX operators benefit from the smaller footprint that allows them to roll out their networks fast and at a price that keeps them profitable.

The cost benefit of compact BTSs can be even greater in emerging markets, where available cellular towers are fewer and where power may be unreliable or, at some locations, not available. With lower power requirements, compact BTSs, especially if coupled with wireless backhaul, can be installed in virtually any location using solar panels or power generators.

Compact BTSs promise to bring cost savings of 38% to 47% over distributed BTSs in capex and opex during a five-year period, depending on BTS configuration and type of operator. WiMAX operators may find compact BTSs playing a key role in strengthening their business case and in accommodating rapidly growing traffic levels from their subscribers.

About Senza Fili Consulting

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We provide a bridge between technologies and services, helping our clients assess established and emerging technologies, leverage these technologies to support new or existing services, and build solid, profitable business models. Independent advice, a strong quantitative orientation, and an international perspective are the hallmarks of our work. For additional information, visit www.senzafiliconsulting.com or contact us at info@senzafiliconsulting.com or +1 425 657 4991.

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