WiMAX: The Future for BWA

Historically, proprietary BWA systems have been predominantly line of sight, which is costly and finicky. However, WiMAX's ability to address link budget and NLOS issues may finally make BWA affordable and practical for the masses.

By David Sumi

BWA has been with us in one form or another for the past ten years or more. During that time, one of the biggest drawbacks to its widespread acceptance has been not only the cost of the SS or CPE, but the installation costs as well. Historically, proprietary broadband wireless access systems have been predominantly LOS, requiring highly skilled labor and a truck roll to install and &quotturn up&quot a customer. As a result, the combined cost of the CPE plus professional installation costs have relegated BWA to the small SME access market, where fees of several hundred dollars per month are acceptable and can support a business plan with those equipment and installation costs.

Moving forward, one of the target markets for BWA is the residential access market, which until now has not been a viable market for BWA. This is because of the vastly reduced monthly access fees in this market, $20 to $30 per month, not being able to support the cost of customer acquisition (CPE price plus installation) with an ROI in any reasonable time frame.

It is widely recognized that with standardization comes volume manufacturing and reduced equipment costs. Systems composed of IEEE 802.16-based WiMAX-certified CPEs will address the cost or price of the end user equipment, leaving the issue of professional installation to be addressed. The concept of a self-installed CPE has been the Holy Grail for BWA from the beginning. With the advent of 802.16 and WiMAX, the question arises: what can or will these new technologies bring to the table in delivering on the promise of self-installation?

Link Budgets and Path Loss

With today's BWA systems, almost 100% of the CPEs are installed outside by professionals striving to achieve a LOS link to BS, a common requirement. This necessitates CPE antennas mounted on poles 20 or 30 feet tall and placed on the roof.

As a result, installation can be complex and expensive. With this as a backdrop, a BWA system where the CPE may sell for $500, and the professional installation adds an additional $500, means a service provider must spend approximately $1000 for each customer, not counting the capital cost of the network infrastructure. Clearly, recovering $1000 at a rate of $30 per month does not present an attractive ROI.

One way to reduce these customer acquisition costs is to reduce the cost of the CPE, and this will happen as a natural result of standardization. The other element to focus on is lowering the installation cost by reducing the installation complexity, or even eliminating it completely, with self-installed indoor devices that can sit on a desktop. The barrier to the indoor CPE has been the large amount of signal loss and reflections, or multipath, which occurs when penetrating the exterior wall of a dwelling. Up until now, systems could only support an indoor installation for those customers very near the BS, approximately 0.25 km or less. Some systems were able to support an indoor install at greater ranges, but at the cost of bandwidth. In these systems, the data rate often falls to a few hundred kb/s. Cell radii of 0.25 km would require so many more BSs to cover a given area that the professional install has been judged the lesser of two evils by today's service provider.

WiMAX and NLOS

Given the challenges to deploying a profitable, competitive BWA network that can serve the residential market, how can WiMAX solve these problems?

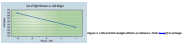
At a very high level, the IEEE 802.16 standard has two key features: the ability to support NLOS operation and the ability to implement and enforce QoS in mixed media traffic. In terms of the self-installed CPE, it is the NLOS feature that bears discussion.

When NLOS deployments are considered, there are two factors that determine how well a system will work and whether or not a customer will be able to receive service: propagation or amount of signal received and multipath or RF reflections. WiMAX-based systems, at their core, employ a waveform called OFDM, which by its

very nature addresses the multipath component of NLOS.

The amount of multipath a system can tolerate is referred to as the delay spread, or how much time passes between the primary signal being received and the reflected signal. In WLAN environments, this value is typically less then 150 ns due to the shorter distances involved. In the BWA environment, delay spread anywhere from 1 to 15µs or even more must be accounted for. With OFDM, the larger the number of sub-carriers or tones translates directly into the amount of delay spread it can tolerate. This is the primary difference between the OFDM used in IEEE 802.11a (64 sub-carriers) and IEEE 802.16 OFDM (256 sub-carriers).

When considering signal propagation, the goal is to improve what is referred to as the link budget which, at a gross level, is comprised of the amount of signal transmitted and the ability to detect that signal at the receiver. These link budgets are measured in terms of decibels or dB, and a typical link budget might be on the order of 130 dB to 150 dB. What is significant is that, for every 6 dB of additional link budget, the range in a LOS deployment doubles. Thus in wireless, improvements in link budgets are typically measured in terms of a few dB (see Figure 1).



When it comes to addressing the signal propagation factor of NLOS, 802.16 and WiMAX address this with a combination of mandatory and optional features. On the mandatory side, WiMAX BWA systems will support techniques such as dynamic modulation and dynamic error correcting code. These techniques do not add to the link budget, they merely help the system to adapt.

Fundamentally, more complex modulations require greater SNR ratios in order to operate at the specified BER of $10^{\&\#150\ 6}$. Greater SNR is achieved largely by increasing the signal level which is done by increasing the link budget or decreasing the range.

QPSK, for example, supports a raw 2 b/Hz spectral efficiency rate while 64 QAM delivers 6 b/Hz. The trade off is range: while QPSK with an error correcting rate of ¾ requires an SNR of roughly 11 dB, 64 QAM with an error correction factor of ¾ requires an SNR on the order of 25 dB. This translates directly to range, with the 64 QAM mode being able to cover on average one fourth the distance of QPSK. With dynamic modulation, the system will be able to reduce its modulation down to

BPSK, a simple modulation scheme that does not deliver a great deal of data (1 b/Hz) but will be able to cover the largest distance. This helps the service provider in that they will be able to reach those long distance customers with BPSK and sell more bandwidth to those 64 QAM-able customers with the same system at the same time. However, these features alone are not enough to have a significant impact on the performance or indoor installation of CPEs.

The reasons for this are simple: distance is a function of link budget versus path loss and the techniques above do nothing to add to the link budget. The WiMAX system link budget landscape can be divided into two main categories:
&#149 WiMAX Mandatory refers to systems that only support those features required by WiMAX. Typical link budgets for these systems will be in the 140 dB range.
&#149 WiMAX Optional refers to those systems that are incorporating advanced features such as Space Time Coding and Diversity Combining, for example. These techniques will increase the link budget to approximately 150 to 160 dB.

Typical RF paths can be broken into three primary types:
&#149 LOS &#151 clear path between CPE and BS. This includes an unobstructed Fresnel zone.
&#149 Near LOS &#151 this situation describes a link where the Fresnel zone is occluded but some direct path signal is received by the CPE. Anywhere from 9 to 12 dB may be lost via partial obstructions (see Figure 2).
&#149 Non LOS &#151 describes an RF path where the entire signal received by the CPE is reflected, i.e. there is no signal reaching the CPE on a direct path from the BS.

To facilitate comparisons between systems, standard definitions of how NLOS a path is have been incorporated into path loss models called SUI models. There are six of these models covering paths from clear LOS to completely obstructed high loss models.

At the end of these three types of RF paths, near the subscriber, the scenario can be broken down further into those that have an outdoor mounted CPE and those that are self-installed indoor.

Clearly, the hope and promise of WiMAX systems for the service provider is to support a NLOS, indoor installed scenario &#151 the most challenging of all.

As noted, additional optional features are available within WiMAX that will enhance the range or ability to deploy indoor CPEs. The most significant of these are turbo codes and STC. STC alone is estimated to add up to 9 dB to the link budget in some severe multipath or NLOS environments. At present, there are only a few chip vendors who are developing WiMAX ASICs.

Beyond WiMAX

With a thorough understanding of the complexities and trade-offs for carriers in terms of BS range, data rates and total cost of ownership, it is clear that not only are the optional features within WiMAX required, but even more needs to be done. In short, chip vendors incorporating additional techniques can greatly extend the range of the indoor self-installed CPE.

For example, a system which employs both sets of optional features mentioned above in a WiMAX chip, as well as taking it an additional step with support for more advanced signal processing and smart antenna techniques, will enhance propagation tremendously. Adding diversity combining using two RF chains within a single 802.16 ASIC, the link budget will improve by 14 to 15 dB when compared to a standard WiMAX system supporting only the mandatory features in a NLOS environment. Adding in other signal processing advantages can raise this to an average of 18 dB. This represents an additional 9 dB over the best results a standard WiMAX system, with optional range enhancing features employed (STC and turbo codes), can deliver.

The Self-installed CPE &#151 Results

As noted previously, it is the first wall penetration that has historically been the primary barrier to self-installed indoor CPEs. Depending on frequency and type of wall, this signal loss can measure from 10 to 20 dB, averaging at 15 dB. For example, at 3.5 GHz with a 3.5 MHz channel size, an average of 16 dB is assumed for first wall penetration. This loss can be offset by the additional link budget generated by incorporating the techniques described above in the MAC/PHY WiMAX ASIC. This means systems employing WiMAX optional features will do well, and those employing diversity and more, on average, will be able to compensate for all of the first wall penetration losses!

In a typical example (see Figure 3), a WiMAX standard system will be able to

support an indoor installation in a suburban environment at a distance of &lt 0.5 km. A system supporting WiMAX options such as STC will be able to support an indoor CPE up to slightly less than 1 km. Advanced solutions can go as far as 1.5 km.

In those situations where the distance is too much even for a SS with every option utilized to be installed indoors, the fully loaded SS with STC and diversity combining will still support up to approximately two to three times the range when compared to standard products. In the worst case where an outdoor installation is mandated, the carrier or service provider will be able to install the SS under the eaves of the house.

This is a task that does not require a $500 professional installation but can be done by a satellite TV technician &#151 an industry that has mastered the $50 installation.

Conclusion

For broadband wireless access to be truly successful, it must be able to serve the residential market. Whether it is in developing nations or developed countries, the consumer appetite for broadband to the home will not support more than $30 per month in service fees for basic Internet access.

It is also evident that for BWA to effectively address this market, the self-installed CPE will play a significant role in reducing the total customer acquisition costs, enabling the overall business case. WiMAX and its associated technologies go a long way to delivering on this promise when both mandatory and optional features are included. But for the best performance available driving installation cost towards zero, a solution which also incorporates advanced signal processing and range extending technologies makes the business case for the residential market work.

About the Author

David Sumi is VP of Marketing at TeleCIS Wireless, a fabless semiconductor company dedicated to delivering multi-protocol wireless System-on-a-Chip (SoC) solutions to the Broadband Wireless Communications industry, and is also Secretary of the WiMAX Forum. Mr. Sumi was one of the early pioneers establishing fixed Broadband Wireless Access as a viable technology and market during its infancy

stages via his work at several start-ups in BWA, including Multipoint Networks, Wireless Inc. and Malibu Networks. His extensive experience in both international and domestic BWA markets, combined with his technical grounding in the RF and networking issues associated with these systems, gives him a solid overall perspective in the Broadband Wireless domain.

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