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Deployment Considerations for Mobile WiMAX

WHITE PAPER

Introduction

Along with traditional factors such as link budgets and signal-to-noise ratio (SNR), deployment considerations for Mobile WiMAX systems should include the cost-saving opportunities offered by the 802.16e standard. For example, the standard allows for the use of low-cost chipsets and enables flexible bandwidth scalability. This white paper provides an overview of these and other considerations involved in deploying Mobile WiMAX technology.

Additionally, this paper concludes with information about how Fujitsu's Mobile WiMAX subscriber SoC and PHY implement cost-effective solutions for 802.16e-2005 broadband wireless access (BWA) systems. With a USB dongle reference design available, this Mobile WiMAX solution is ready for immediate use.

Designing a Mobile WiMAX Network

A wide variety of technical points need to be considered when designing a Mobile WiMAX network. A significant consideration is the efficiency (cost and performance) involved in providing coverage and capacity, while avoiding the build-out of a large number of new cell sites.

The first item to consider is the link budget — the loss and gain sum of signal strength through the varying medium of the transmission path. The link budget determines the maximum cell radius for an adequate service-level agreement (SLA). Additionally a good SNR is critical for the system to perform at the optimum level.

As mentioned earlier, the 802.16e standard will reduce the cost of mobile deployments by enabling VARs to use the chipsets originally intended for laptops and PDAs. These chipsets can be leveraged in the manufacture of indoor and outdoor fixed customer premises equipment for WiMAX. 802.16e and offers the critical advantage of allowing the operator to think about cost savings for serving large coverage areas.

Another benefit of the 802.16e OFDMA specification is that the bandwidth of the system is easily scalable because of the fixed relationship between the occupied bandwidth and the OFDM symbol sample rate. While several sample rates are enabled by the 802.16e standard's specification of fast Fourier transform (FFT) sizes of 128, 512, 1024, and 2048, the subcarrier separation and symbol duration remain constant as the deployment bandwidth changes. The ability to scale while maintaining constant symbol duration provides more flexibility in equipment components. Most importantly, operators can deploy systems today and grow system bandwidth in the future at lower cost — without impact to earlier deployments.

Environmental Factors

Wireless design criteria vary across four types of environments:

- **Dense Urban** — A city center with many businesses and high-density residential units represents a challenge due to multipath effects among the multi-story buildings.
- **Urban** — Surrounding a city center, average building heights may be lower than the mast of a base station, but the propagation environment remains equally challenging.
- **Suburban** — With lower-density housing (primarily single-family dwellings) and fewer businesses, average building heights are much lower than base station towers and structures are more spread out, thus creating a more favorable propagation environment.
- **Rural** — Where homes are far apart and businesses widely scattered, this environment offers no obstruction to wireless propagation so long as the terrain is flat.

Determining Coverage Boundaries

To take full advantage of WiMAX scalability, system operators need to use the right software tools to predetermine coverage boundaries. These tools perform propagation simulation and drive tests. Careful deployment planning is critical in order to have room to scale, anticipating growing customer demands while ensuring a quality user experience. This planning is especially important in urban areas, where deployments are most likely to be driven by capacity requirements.

Population density and population growth rates are easily obtained for any metropolitan area by referring to census data. When considering mobile services the addressable market can be assumed to be any individual within a certain age group. The specific age group targeted may differ from operator to operator based on planned services and population density data.

Sector and Frequency Reuse

A 3-sector base station is standard for cellular and PCS systems, and it also suits WiMAX systems (Figure 1). To make best use of the available wireless spectrum, WiMAX systems can utilize both sector and frequency reuse. Sector reuse is using one sector to cover multiple areas, at least one of which is closer to another base station. Frequency reuse is using a frequency to serve multiple sectors that do not mutually interfere.

With a frequency reuse of 1, each of a base station's three sectors use the same channel (thus effectively combining the three sectors into a single sector).
A frequency reuse of 3 eliminates co-channel interference at the sector boundaries. This reuse also significantly decreases co-channel interference between neighboring cells due to the increased spatial separation for channels operating at the same frequency — provided that the cell sector boundaries are properly aligned. Getting the right alignment involves down-tilting antennas and performing drive tests to see if each sector covers the proposed azimuths. The inherent properties of Mobile WiMAX's Orthogonal Frequency Division Multiple Access (OFDMA) scheme controls adjacent channel interference (ACI) at the sector boundaries.

Frequency Band and Other Considerations

Calculations for link margins and SNR must include a number of factors, mostly related to the deployment environment and quality of service goals. The chosen Mobile WiMAX implementation technology strongly influences these tradeoffs.

Because of the importance of good reception inside buildings and vehicles, penetration loss must be taken into account by utilizing the normalization factor (n-factor) for a given medium. The n-factor depends on the modulation and is used to achieve the same average power for all mappings. The modulation is based on Quadrature Amplitude Modulation (QAM) with 2M points constellation, where M is the number of bits transmitted per modulated symbol. For Mobile WiMAX downlinks, 4QAM (QPSK, M = 2) and 16QAM (M = 4) are mandatory, while 64QAM (M = 6) is optional. For uplinks, 4QAM is mandatory and 16QAM is optional.

As a propagation model for making calculations, Mobile WiMAX deployments can take advantage of the Modified Hata COST 231 model. This widely used version of the COST 231 model is suitable for mobile applications in the 1900 MHz band and acceptable for the 2500 MHz and 3500 MHz bands.

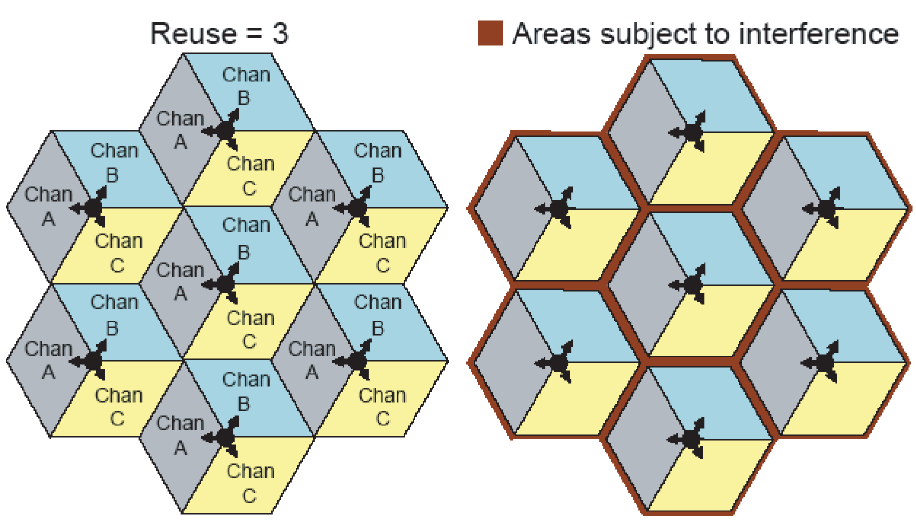

Figure 1 – 3-Sector Wireless System with Frequency (Channel) Reuse

Another factor is antenna gain, which can be used to increase coverage with the tradeoff that increasing gain decreases the carrier-to-interference-plus-noise ratio (CINR). A CINR of 25 dB or better is normal.

Other link parameters including fade margins and interference margins are assumed to be the same for each of the frequency bands — 2.5 GHz, 3.5 GHz and eventually 5.8 GHz bands.

Beamforming Benefits

As described in a joint Cisco/Fujitsu white paper (http://us.fujitsu.com/micro/wimax/beamforming), beamforming improves both the range and capacity of a WiMAX network at a relatively low implementation cost. Beamforming reduces capital and operating expenses for WiMAX implementations by minimizing the number of base stations needed in a network. This technique is especially useful for Mobile WiMAX systems, which must minimize interference while providing good coverage in all parts of the environment for mobile subscribers.

Beamforming uses an advanced antenna system (AAS) and multi-signal processing techniques to direct transmission power where it is needed — toward specific Mobile WiMAX receivers. Rather than send one high-powered signal, the system sends multiple small signals such that they combine at the end-user terminal but cancel each other out in other places.

To do beamforming well, the system needs to take “sounding” measurements on the uplink and apply corrections to the downlink based on these measurements. This fast feedback-based approach is called adaptive beamforming, and it demands a great deal of signal processing. More specifically, an adaptive beamforming system measures the characteristics of signals arriving by multiple paths (multipaths) from a mobile subscriber. These characteristics include relative signal strengths, phases, and angles of arrival. The system then creates a map of the best downlink paths to the device. The downlink signal is sent using the best available multipaths, such that the reflected signals all arrive at the subscriber device together and in phase.

The result is a much higher SNR than is otherwise possible. This high SNR enables the use of higher orders of modulation, meaning that the signal can be transmitted and decoded using higher-order symbols, such as 64QAM. This capability equates to higher download speeds and faster response time.

Beamforming thus addresses the fundamental power problem encountered in delivering personal broadband with high data rates. With beamforming, a base station does not need enough RF power to broadcast high data rates to every part of the coverage area simultaneously. Base stations can apply their power selectively, thus providing excellent coverage at lower cost.

All customer devices must support beamforming as part of the WiMAX Forum Wave 2 certification for PHY and MAC features. However, the quality of the beamforming implementation varies considerably from one vendor to another. Interoperability tests and other evaluations have shown that Fujitsu’s mobile subscriber SoC offers excellent penetration and flawless performance.

Fujitsu’s Mobile Subscriber SoC

The Fujitsu MB86K21 Mobile WiMAX SoC fully complies with the IEEE 802.16e-2005 standard utilizing a scalable OFDMA PHY (the MB86K71 MIMO RF module). The SoC operates in Time Division Duplex (TDD) mode and supports 5-MHz bandwidth with 512 FFT points and 10-MHz bandwidth with 1024 FFT points. Additionally, the SoC supports DL_PUSC, DL_FUSC, DL_AMC 2x3, UL_PUSC and UL_AMC 2x3.

Fujitsu offers a USB dongle reference design based on the baseband SoC and RF module. This dongle has been proven to work efficiently in all types of metropolitan areas.

The Fujitsu mobile subscriber SoC supports MIMO Matrix A, which gives users the best possible coverage in any given geographical area. The device’s capability has been proven to increase throughput in the presence of multipath while correlating two incoming signals.

The two signals are part of the standard Matrix A method to improve coverage gain. This method uses two transmitting antennas and two receiving antennas, with a single data stream transmitted in parallel over two paths made possible by the dual antennas. To improve the SNR at the receiver, the data streams are encoded to be mutually orthogonal using an algorithm called Space Time Block Codes (STBC). By improving SNR, the Matrix A method allows service providers to use bigger cells while achieving better throughput for all subscribers.

The Matrix A method is a multiple-input/multiple-output (MIMO) system. MIMO uses multiple antennas to send and receive data streams via different spatial paths in the physical environment. Even if the data streams are transmitted at the same frequency, they follow different spatial paths (multipath). The receiver can use signal processing to sort out the two streams and recover the original data.

Although multipath signals create reception difficulties for traditional wireless systems, multipath radio signals can actually be beneficial when using MIMO. A MIMO system can use multipath for addition spatial “channels” of data transmission.

Additionally, non-line-of-sight (NLOS) capabilities of Fujitsu’s mobile subscriber SoC enable communication through walls and other physical obstacles in both urban and rural environments. This type of capability has been fully tested and ready for a rapid deployment. Employing smart antenna technology including beamforming capabilities, power control and other standard-defined parameters means that Fujitsu’s mobile subscriber maximizes the number of services delivered and their quality regardless of the operating environment.

Conclusion

When considering Mobile WiMAX deployment factors such as link budgets and SNR as described in this white paper, one of the most important factors is the technology used to implement both base stations and subscriber equipment. Fujitsu’s Mobile WiMAX technology provides high-quality, mobile broadband multimedia services in a versatile implementation that suits a wide range of application requirements.

For More Information

More information on the IEEE 802.16 standard for broadband wireless access and the WiMAX Forum is available at www.ieee802.org/16 and www.wimaxforum.org, respectively.

For more information on Fujitsu’s broadband wireless SoC, please go to http://us.fujitsu.com/micro/wimax, or address e-mail to inquiry.bwa@fma.fujitsu.com.

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Printed in U.S.A. BWA-WP-21335-9/2008