POWER CONTROL AND ANTENNA GAIN OPTIMIZATION DURING WIMAX HANDOVER

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Abstract

Wireless systems have recently been becoming faster and more intelligent. However the high speed access and intelligence make the power consumption of wireless systems high. In the WiMAX system, the MS transmission power is controlled in order to avoid exceeding the BS's total receiving power from an antenna. Conventional wireless network design has long used base site sectorization and single, omni-directional antennas at the end-user device to serve the communications link, with advanced multi-antenna implementations operators have a new suite of tools to develop the robust wireless networks of the future. Revolutionary multiple antenna techniques at the base station and end-user device, paired with sophisticated signal processing and power consumption control, can dramatically improve the communications link for the most demanding application scenarios including heavily obstructed propagation environments and high speed mobility service. This paper presents results of an experimental study, simulation based, directed to determine the optimum transmission power and Antenna gain which influence on the overall handover performance in mobility scenarios, related to WiMAX communications. Based on them, optimal parameter sets can be provided by the network operator to mobile station, to guide its adaptation of the major WiMAX parameters to its speed and network topology and to help the handover decision.

Keywords**:** WiMAX; MS Transmission Power; Antenna Gain; OPNET Modeler.

1. Introduction

Wireless operators are increasingly pressured to enhance their networks and service capabilities in order to keep pace with the accelerating growth in wireless utilization and increasing demand for high performing connections. As bandwidth intensive, rich media applications are introduced, larger volumes of subscribers consume ever-growing quantities of data packets while continuing to utilize more minutes of voice. Simply acquiring more spectrum channels and deploying more sites to resolve capacity issues can be decidedly inefficient and costly. Mobile WiMAX [1] has offered the industry a very capable platform by which to deliver the demanding service requirements for wireless broadband systems. Wireless systems have recently been becoming faster and more intelligent. However the high speed access and intelligence make the power consumption of wireless systems high. MS power consumption is one of the main issues for wireless broadband systems. Where conventional wireless network design has long used base site sectorization and single, omni-directional antennas at the end-user device to serve the communications link, with advanced multi-antenna implemen¬tations operators have a new suite of tools to develop the robust wireless networks of the future.Multi-antenna implementations such as MIMO and beamforming offer opportunities to enhance in-building penetration, coverage and capacity in even the most challenging environments. By combining the performance advantages of WiMAX with sophisticated antenna implementations and power consumption control, WiMAX operators can rapidly deploy an optimized network tuned to the varying requirements in their service footprint today and easily grow and scale to meet the growing demands of tomorrow.

Given the high number of WiMAX physical and MAC layer parameters influencing in an inter-dependent mode the overall performance in mobility scenarios, experimental simulation studies of complex scenarios are very helpful to determine the combined effect on such parameters. The effect at different PHY parameters adjustments on the throughput values has been evaluated. The optimal parameter sets obtained from simulations can be provided by a network operator to mobile station (MS), helping it to adapt dynamically its behavior and to obtain the maximum throughput possible from network at different speed, antenna gain and maximum transmission (Tx power). The results can be used as a method of optimizing the vehicular communications by guiding the handover (HO) decision.

In [2], mobile WiMAX trials are analyzed to investigate the vehicular downlink performance for a number of on-car antenna configurations. This work presented is a continuation of a set of complex studies on WiMAX mobility. First results have been shown in a study of HO performance for WiMAX mobility [3], continued with an WiMAX HO conditions evaluation towards enhancement through cross-layer interaction proposed in [4], together with a SIP-based cross-layer optimization for WiMAX Hard HO method, described in [5].

2. WiMAX Parameters

2.1. *Transmission Power in WiMAX*

In the WiMAX system, the BS controls the transmission power of the MS in the same way as in the code division multiple access system. In the WiMAX system, the MS transmission power is controlled in order to avoid exceeding the BS's total receiving power from an antenna. In the WiMAX standard, other uses of it are not defined. The WiMAX system supports adaptive modulation and coding (AMC), which varies the modulation, such as quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM), or the error correction coding rate according to the wireless channel quality.For the MS to transmit a signal , the BS determines the modulation and coding scheme (MCS) by observing the signal to interference and noise ratio (SINR) of the received signal. MCS information is transmitted for each MS. If the NR is good, the MS can use high speed modulation and a small amount of error correction code, so a high transmission rate can be achieved. One way to improve the SINR is for the MS to transmit at high power. (ie by increasing the signal strength). However, increasing the transmission power increases the battery power consumption, so the battery lifetime becomes shorter. In the WiMAX system, the BS assigns subchannels for each subordinate MS to avoid interference, but if the MS transmission power is increased, it might interfere with MSs under other BSs. An MS that experiences interference with its signal increases the transmission power to maintain the transmission rate. This shortens the battery lifetime even more. As the battery lifetime is critical for an MS, it is very important to control the MS transmission power, taking into consideration the transmission rate and battery lifetime.

2.2. *Antenna Gain in WiMAX*

One of the greatest challenges to traditional wireless systems has been managing multi-path fading environments. Multi-path fading is the resulting signal degradation due to obstructions between a wireless transmitter and its intended destination. In a Non Line of Sight (NLOS) environment, a transmitted signal may bounce off of a myriad of obstacles including buildings, roads, and man-made structures as well as trees, hills, and naturally occurring impediments. These multiple, "bounced" signals may interfere with one another resulting in a degraded signal at the receiver. Perhaps somewhat counter-intuitive, where multipath and challenging propagation environments were once considered an adversary to wireless systems, with multi-antenna implementations, the wireless system actually benefits from the multipath phenomenon – leveraging multipath to create a more robust communications channel. Current cellular standards use multiple antennas at the base station to provide diversity gain. In contrast, MIMO wireless technology makes use of multiple antennas at both the transmitter (base station) and receiver (mobile terminals) in combination with specially designed algorithms to provide both capacity and diversity gains using the same bandwidth and power as single antenna systems. While it is evident that shifting to MIMO will require two or more antennas at the receiver side, it is not clear if this transition will require a change in the existing antenna designs at the base station. Base stations use multiple antennas for reasons of diversity. The diversity gain obtained increases as the spatial correlation between signals reduces.

Effective antenna designs can be used to improve MIMO performance by utilizing the following three antenna diversity effects:
1) Spatial diversity - spacing antenna elements far apart,
2) Pattern diversity - using antenna elements with orthogonal radiation patterns,
3) Polarization diversity - using antenna elements with different (orthogonal) polarizations, example, the HV polarized array, dual pol array etc.

3. Joint Power Consumption Control and Antenna Beam-Forming

We propose a power consumption control scheme where the lowest rate MCS is used as much as possible because the required transmission power is the lowest. The behavior of our scheme is shown in figure 1. Specifically, the BS designates the lowest-rate MCS such as QPSK ½ for each MS when all the data requested to be transmitted from MSs can be transmitted using that MCS. A transmission power for each MS is also designated as the minimum level that guarantees transmission in that scheme. If the total data requested to be transmitted exceeds the transmission capacity for that MCS, the BS selects an MS that does not interfere with most of the MSs under other BSs and designates a higher rate MCS for that MS by boosting the MS transmission power to a level that guarantees transmission, using the new MCS. Using the higher rate MCS reduces the air resources required for the MS. Consequently, the BS can allocate the released resources to other MSs. To select the MS that interferes the least with MSs under other BSs, the transmission power of the MS is used as a measure. If the MCS of each MS is the same, the transmission power of the MS suffering the least interference from MSs under other BSs is the lowest because the required SINR is the same. This is because the effect of interference is symmetrical; in other words, the MS receiving the least interference causes the least interference. The MS that transmits at the lowest power is selected as the MS to send at the higher rate MCS at the higher transmission power.

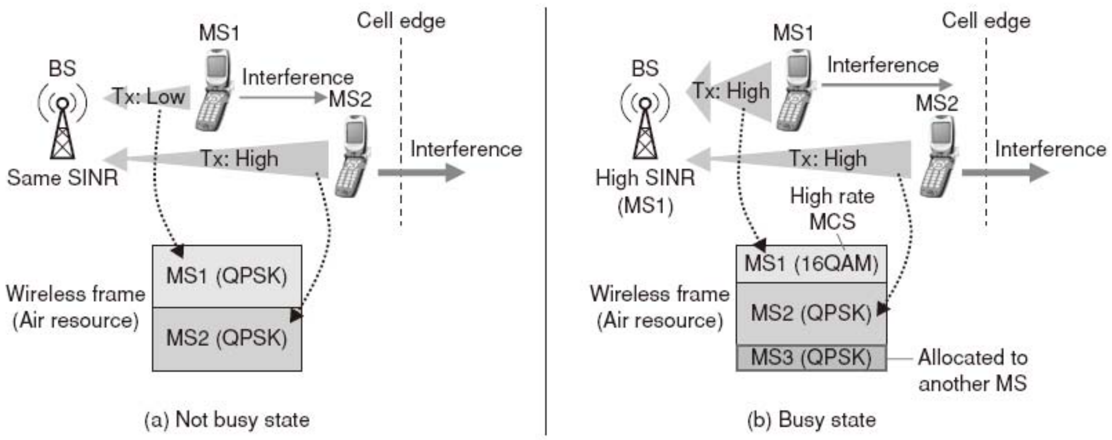

Fig. 1. Proposed Power Consumption Control Scheme

WiMAX systems that use beamforming (figure 2) as a means to further increase system coverage and capacity can surpass the capabilities of MIMO techniques. The transmission of signals from several antennas at specific relative phases can be used to create a much narrower antenna beam giving rise to the name 'beam-forming'. Beam-forming does require knowledge of a subscriber's location making it more challenging to implement for subscribers moving at high speeds. Beamforming techniques such as Statistical Eigen Beamforming (EBF) and Maximum Ratio Transmission (MRT) are optional features in the 802.16e WiMAX standard, but leading vendors are taking advantage of its strong performance characteristics. Beamforming techniques leverage arrays of transmit and receive antennas to control the directionality and shape of the radiation pattern. The antenna elements have spatial separation dictated by the wavelength of transmission and are supported by sophisticated signal processing.

Channel information is communicated from the WiMAX subscriber to the WiMAX base station using the "uplink sounding response" – a mandated device feature for WiMAX certification. Based on the understanding of the channel characteristics, the WiMAX base station utilizes signal processing techniques to calculate weights to be assigned to each transmitter controlling the phase and relative amplitude of the signals. By leveraging constructive and destructive interference, the radiation pattern is steered and formed to provide an optimal radiation pattern focused in the direction of communication.

When transmitting a signal, beamforming can increase the power in the direction the signal is to be sent. When receiving a signal, beamforming can increase the receiver sensitivity in the direction of the wanted signals and decrease the sensitivity in the direction of interference and noise. While the processing requirements for beamforming can be quite sophisticated and resource intensive depending on the complexity of the channel and the number of subscribers on the system, today's implementations can resolve the beam weights within 5 to 10 ms allowing for practical WiMAX solutions.

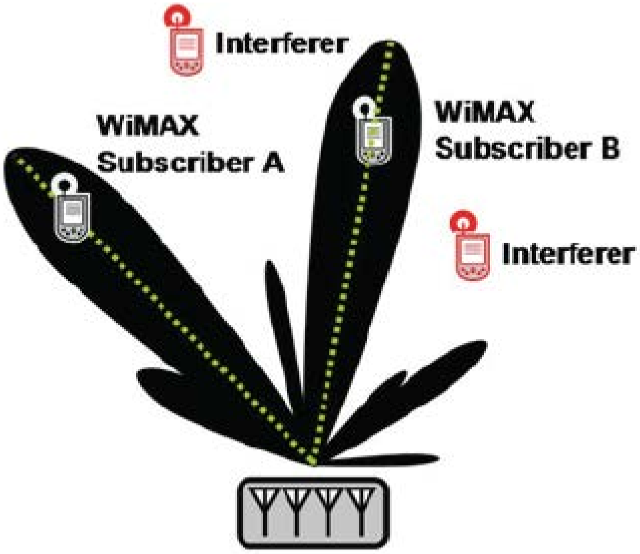

Fig. 2. Beamforming

Beamforming techniques allow the WiMAX system to realize increased range with higher antenna gain in the desired direction of communications and better connectivity between the base station and device. Simultaneously, the narrower beamwidth and reduced interference increases the capacity and throughput offered by the system.

While both MRT and EBF are similar techniques in principal, the algorithms supporting each offer advantages in varying application scenarios. For MRT to deliver strong system gains, the technique requires a more exact measurement and understanding of the channel conditions. As such, MRT is a more opportune technique when communicating with static receivers. For mobile receivers, the delay between measuring the channel condition and forming the beam becomes a significant factor for delivering the necessary system gains. In these mobile environments, EBF offers a more robust technique. Ideally, WiMAX beamforming solutions would adopt both MRT and EBF techniques to provide a more holistic beamforming solution that capably addresses both fixed and mobile applications.

4. Performance Analysis

Revolutionary multiple antenna techniques at the base station and end-user device, paired with sophisticated signal processing and power consumption control, can dramatically improve the communications link for the most demanding application scenarios including heavily obstructed propagation environments and high speed mobility service. With the added support for a variety of advanced multi-antenna implementations and power consumption control, Mobile WiMAX offers the wireless operator considerable relief in meeting their growing network demands with higher performance, fewer sites, less spectrum, and reduced cost.

There are numerous studies about WiMAX mobility and methods of optimizing the Handover communications. However, an analysis of WiMAX system behavior on incremental variance of speed, antenna gain and maximum Tx power could add new value to existing optimization methods.

All simulations were done in OPNET v.14.5. [6] A typical mobility scenario has been considered (linear trajectory along a road where WiMAX BS stations are located). The BSs use the same set of frequencies and the mobile station (MS) is moving on a linear trajectory along the chain of BSs. The utility of such a scenario is that it is similar with a road region in which WiMAX station are located along the road and the MS is a vehicle moving on the road. Figure 3 shows the throughput graph obtained for the existing (WiMAX-IJCSE 2-DES-1) and proposed schemes (WiMAX-IJCSE 1-DES-1). From the graph it is clear that the adptive power consumption control with antenna gain increases the overall performance of the WiMAX system during Handover.

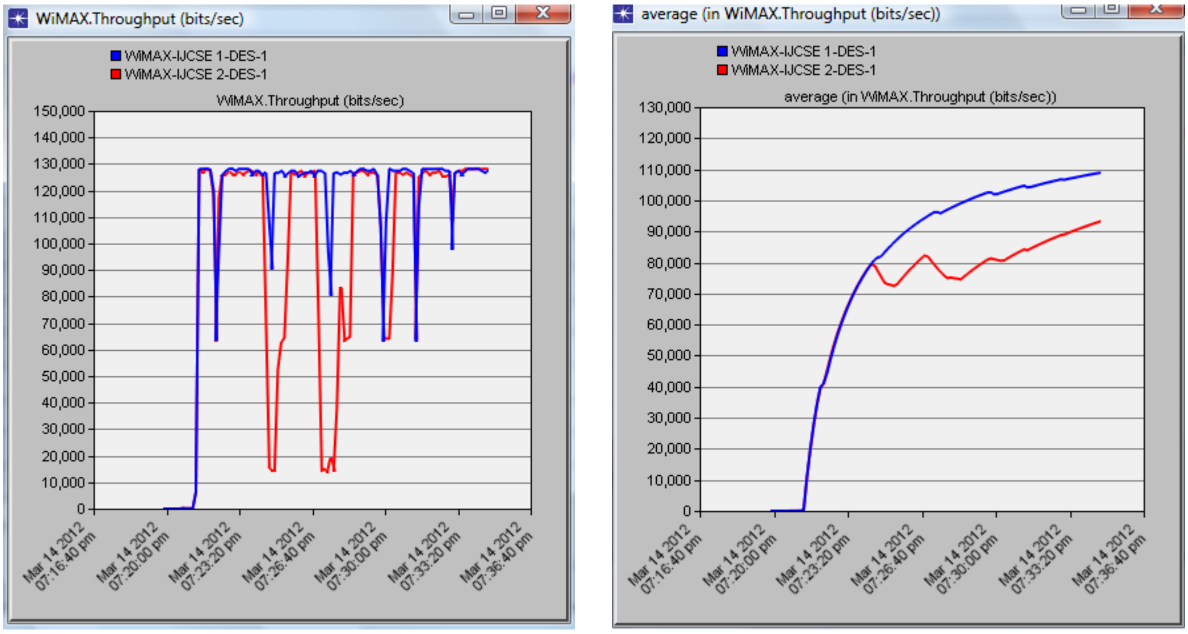

Fig. 3. Throughput Graph

5. Conclusion

The analysis of Mobile WiMAX system behavior on incremental variance of speed, antenna gain and maximum Tx power, provides a database usable for optimization methods/techniques. Each simulation allow not only the combined effect details of a pair of parameters variance, but allow to predict the system behavior for each specific parameter value. Network operator could use such kind of extended simulations for different roads and highway, where the network topology and the road details are known. Vehicles provided with WiMAX terminal capabilities passing these roads could be helped to optimize the communications using cross layer-algorithm based on location and speed prediction from GPS information and optimal parameters set from network operator.

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