OPTIMIZATION OF DECISION TAKING ALGORITHM FOR WiMAX HANDOVER

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Abstract

Mobility is the most important feature of a wireless cellular communication system. The IEEE standard 802.16E-2005 provides enhancements to IEEE standard 802.16-2004 to support subscriber stations (SS) moving at vehicular speeds. Although the IEEE 802.16e standard proposes to tackle this problem, the disruption time (DT) of handover is still too long to overcome the maximum delay time of real-time services such as VoIP and video bit streaming. To deal with these problems, we propose to optimize the decision taking algorithm parameters Modulation/coding, Scanning Threshold and Base Station & Mobile Station Antenna gain. The performance of our decision taking algorithm is evaluated using OPNET simulations.

Key words: WiMAX, Modulation/Coding, Scanning Threshold, Handover, OPNET.

I. INTRODUCTION

WiMAX (also known as IEEE 802.16) is a wireless digital communications system that is intended for wireless "metropolitan area networks" (WMAN). It can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 – 10 miles (5 – 15 km) for mobile stations. The IEEE 802.16 group was formed in 1998 to develop an air-interface standard for wireless broadband. The group's initial focus was the development of a LOS-based point-to-multipoint wireless broadband system for operation in the 10GHz–66GHz millimeter wave band. The IEEE 802.16 group subsequently produced 802.16a, an amendment to the standard, to include NLOS applications in the 2GHz–11GHz band, using an orthogonal frequency division multiplexing (OFDM)-based physical layer. These early WiMAX solutions based on IEEE 802.16-2004 targeted fixed applications, and these will be referred to as fixed WiMAX. In December 2005, the IEEE group completed and approved IFEEE 802.16e-2005, an amendment to the IEEE 802.16-2004 standard that added mobility support. The IEEE 802.16e-2005 forms the basis for the WiMAX solution for nomadic and mobile applications and is often referred to as mobile WiMAX [1],[2],[3]. Mobility is the most important feature of a wireless cellular communication system. Usually, continuous service is achieved by supporting handover from one cell to another. The IEEE standard 802.16e-2005 provides enhancements to IEEE standard 802.16-2004 to support subscriber stations (SS) moving at vehicular speeds. It thereby specifies a system for combined fixed and mobile broadband wireless access without compromising the capabilities of fixed IEEE 802.16 subscribers. Functions to support handover at higher layers between base stations are specified. It is essential to provide continuous services of multimedia streaming data when a mobile subscriber station (MSS) undergoes handover. Although the IEEE 802.16e standard proposes to tackle this problem, the disruption time (DT) of handover is still too long to overcome the maximum delay time of real-time services such as VoIP and video bit streaming. In MWiMAX, a handover initiation decision by a wireless terminal or BS is dependent on the Received Signal Strengths (RSS) from the current serving BS (SBS) and the neighbouring BSs (NBS). The MS and the SBS jointly decide on when to initiate a handover activity.

Whenever the RSS from the SBS drops below a certain threshold, which might hamper an ongoing communication session, the MS goes for a handover with one of the chosen NBSs, called the target BS (TBS). When the MS moves with high velocity, the rapid change of channel condition makes pre obtained information useless. So during actual HO procedure, the neighbouring BSs scanning and contention based ranging operation must be performed, which generates a long handover delay and wireless channel resource waste at higher speed of the MS.

To deal with these problems, we optimize the decision taking algorithm using the three handover parameters Modulation/coding, Scanning Threshold and Base Station & Mobile Station Antenna gain. The major purpose of our proposed handover scheme is to reduce the data transmission latency in the handover process including the delay during the scanning for the target BS selection and increase the throughput of the WiMAX network. Various experiments are conducted to find the optimized values of MS speed, Scan threshold, Modulation & Coding and Antenna gain. One such optimized result is considered for our proposed system and the performance improvement is shown in terms of throughput.

II. HANDOVER PARAMETERS

A. Modulation and Coding Scheme in WiMAX

The following section will provide a brief description of the modulation and coding of Mobile WiMAX.

Modulation

Table 1. Receiver Minimum Input Sensitivity

Bandwidth (MHz)	QPSK		16-QAM		64-QAM	
	1⁄2	3⁄4	1⁄2	3⁄4	2⁄3	3⁄4
1.5	– 91	– 89	– 84	– 82	– 78	– 76
1.75	– 90	– 87	– 83	– 81	– 77	– 75
3	– 88	– 86	– 81	– 79	– 75	– 73
3.5	– 87	– 85	– 80	– 78	– 74	– 72
5	– 86	– 84	– 79	– 77	– 73	– 71
6	– 85	– 83	– 78	– 76	– 72	– 70
7	– 84	– 82	– 77	– 75	– 71	– 69
10	– 83	– 81	– 76	– 74	– 70	– 68
12	– 82	– 80	– 75	– 73	– 69	– 67
14	– 81	– 79	– 74	– 72	– 68	– 66
20	– 80	– 78	– 73	– 71	– 67	– 65

This subsection will list up the modulation types that are optional and mandatory by the WiMAX Forum. In the downlink, QPSK, 16QAM, and 64QAM are all mandatory modulation types. 64QAM are however optional in the uplink. Table 3 shows the minimum sensitivity level for each modulation and coding rate per bandwidth, where the BER is less than 10-6. however, converts the BER requirement with assumptions to SNR requirements for the MCS, in an AWGN environment. The relationship between BER and Bit/Symbol energy, EB=N0, can be found both mathematical and graphical.

Coding

Channel coding is a way to increase the robustness of a channel by including randomization, interleaving, repetition, and error correction prior to modulation. Forward error correction (FEC) adds redundant bit to the information bits, allowing the receiver to detect and correct errors. The code rate decides how many coded bits that represent the information bit. The supported code rates of Mobile WiMAX are: 1/2, 2/3, 3/4, and 5/6.

Adaptive Modulation AND Coding

WiMAX utilizes an adaptive modulation and coding scheme together with BPSK, QPSK and QAM modulation schemes [4]. The adaptive modulation allows the highest order modulation to be chosen according to the channel conditions. As we increase our range, we step down to lower order modulations, but as we reduce our range, we can use higher order modulations such as QAM for increased throughput. The standard also supports repetition coding of rate 1, 2, 4, or 6. This can, in theory, be used in combination with any modulation and coding scheme.

Table 2. AMC Schemes And Receiver SNR Assumptions

Modulation	Coding	Receiver SNR
BPSK	1/2	3
QPSK	1/2	6
	3/4	8.5
16-QAM	1/2	11.5
	3/4	15
64-QAM	2/3	19
	3/4	21

Repetition coding can be used to lower the required receiver sensitivity and hence increase the cell range. However, the penalty will be a reduction in capacity in line with the rate selected because every transmission will be repeated multiple times. The network planner needs to consider the use of repetition coding in line with the deployment requirements (for coverage or capacity).

An AMC scheme is applied in order to compensate downlink channel fluctuations during transmission. The scheme enables the system to transmit with higher data rates in good channel conditions and avoid excessive packet dropping in poor channel conditions by reducing data rate. Therefore, efficient bandwidth utilization and high throughput can be achieved. Proposed AMC enables the scheduler to select the appropriate coding and modulation for each allocation.

Thus, users in handover zone achieve higher data rates and better throughput, since the scheduler gives higher priorities to them. Several AMC schemes are proposed, namely, 16-state and 64-state Quadrature Amplitude Modulation (QAM), Quadrature Phase Shift Keying QPSK) and Binary Phase Shift Keying (BPSK) with coding rates of 1/2, 2/3 and 3/4, as shown in Table 2.

B. Scanning Threshold

Handover procedures include numerous means of optimization. In particular, to reduce time expenses for the mobile to find the central frequency and acquire parameters of the neighbor base station, the mobile can apply a scanning process [5] when the mobile is away from the serving base station to scan the wireless

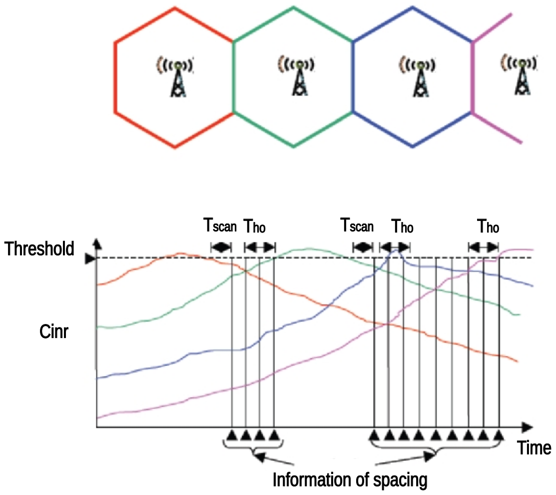

Fig. 1 Scanning

media for neighbor base stations. Information collected during scanning such as central frequencies of the neighbor base stations can then be sued in actual handover. In some deployment scenarios, scanning can be performed without service interruption. For this purpose, information about the central frequency and parameters of the neighbor base stations is periodically advertised by the serving base station.

The operation of an MSS can be assumed as follows. Although, it can be an implementation issue to decide when an MSS starts to scan neighbor BSs and performs handover to other BSs.

- An MSS can measure the signal power from the SBS without any scanning request message.
- An MSS starts to scan neighbor BSs, if the signal power from the SBS is lower than a given threshold for Tscan time.
- The handover procedure will be started, if the signal power of other BS is higher than that of SBS for Tho time.

As shown figure 1, an MSS should scan neighbor BSs frequently in handover region. The MSS or the SBS may request periodic scanning if the MSS is considered in the handover region.

A short summary of scanning process is given here as reminder. When the fading SNR reaches the scanning threshold, the MS begins with scanning process on the announced DL channels by sending the MOB-SCN-REQ message. The BS allows for scanning by replying with the MOB-SCN-RSP message that contains the parameters for scan duration (N), interleaving interval (P) and the start frame (M). After receiving the MOB-SCN-RSP from the target BS, the SS starts the scanning after M received frames (start frame). The SS changes after M frames to the next channel and stays there for an N frames period (scanning interval/duration) to detect a BS and to assess its SNR.

After a scanning interval, the SS returns to the DL channel of the active BS. This behavior aims to keep the interruption as short as possible since no payload transmissions are possible during the scanning process. If no preferable BS could be detected on the scanned channel, it reinitiates the scanning mode after a P frames period (interleaving interval) to find a new

BS. The total number of allowed repetitions of the scanning process is given with the parameter (T).

Table 3. Scanning Parameter

Scanning method	Cx1	Cx2	Cx3	Cx4	Cx5	Cx6
Scanning Threshold	10	20	30	40	50	60
N (frames)	30	25	20	15	10	5
P (frames)	50	100	150	200	250	250
T	10	10	10	10	10	10

It is seen that Cx1 represents a scanning method having relative large N/P ratio, i.e. the relative time spent with the scanning is larger versus the time spent to transmit the data payload. At the other end of the range, Cx6 has small N/P, i.e. the scanning relative time is less than the time spent for data transmission. On the other side, the scanning threshold has been adjusted as to compensate in a certain measure this scarcity of spanning activity, by taking a higher value of the scanning threshold (60 DB).

B. Antenna Gain

Cellular standards like the third generation partnership program (3GPP) long term evolution (LTE), ultra-mobile broadband (UMB), high speed downlink packet access (HSDPA) and IEEE 802.16e (WiMAX) support multiple-input multiple-output (MIMO) wireless communication technology. MIMO uses multiple antennas at the transmitter and receiver along with advanced digital signal processing to improve link quality and capacity. Existing base station use antenna arrays to provide transmit and receive diversity; it is not clear if shifting to MIMO will require a change in the base station antenna designs.

Current cellular standards use multiple antennas [6] 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 capacity1 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. In MIMO, the relationship between spatial correlation and performance is more complex. For example, at the edge of the cell where signal strength is low, it is preferable to use diversity-based single stream transmission strategies that require one of the spatial channels to be significantly stronger than the others.

This is possible when the spatial correlation between signals received at the antenna elements is high. In contrast, when the signal strength is high (near the base station), it is beneficial to use spatial multiplexing strategies to increase the capacity. In this situation, spatial correlation among received signals lowers the capacity gains obtained. Thus, spatial correlation has different implications in diversity-based and MIMO systems. This is the primary reason for the difference in the design principles for diversity-based and MIMO antenna arrays.

Spatial correlation might arise due to the antenna arrays employed at the transmitter and receiver (small inter-element spacing, mutual coupling etc.) or due to the channel characteristics. If the wireless propagation environment has sufficient multipath, the channel spatial correlation is generally low. In contrast, when the channel does not have rich multipath or when a strong line of sight exists between the transmitter and receiver, the channel spatial correlation is considerably higher.

The impact of high channel spatial correlation can be lowered using effective MIMO antenna design techniques. For example, by using antenna arrays where the elements have orthogonal polarizations or patterns, the spatial correlation of the signals received at the antenna array can be significantly reduced, even when the channel spatial correlation is high. By spacing antenna elements far apart, or by using elements that have orthogonal radiation patterns or polarizations, it can be ensured that signals received at these antenna elements have undergone independent scattering in the propagation environment and hence, have low correlation.

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.

III. NETWORK SETUP

The network consists of 8 Base Stations, Single Mobile Station and an IP backbone (Fig. 2).

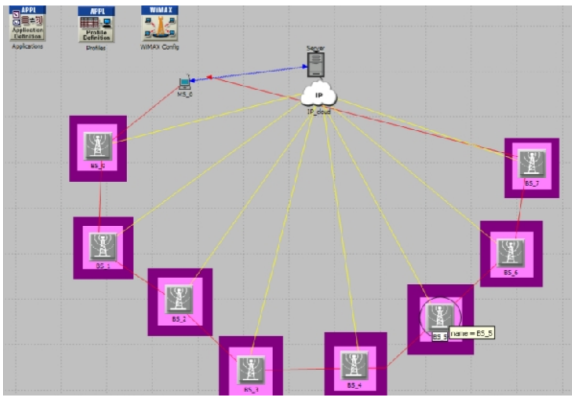

Fig. 2. Network Setup

There is a server backbone containing one server including Application server and three configurations are used they are, application configuration, profile configuration and WiMAX configuration. Mobile Station Transmission Power is set to 0.5 W. Base Station Transmission Power is set to be 5W. The Pathloss and Multipath Model are set to Pedestrian. The trajectory set for different speeds i.e., 10 m/s, 20 m/s, 30 m/s and 40 m/s. The Network model is same for both existing and proposing system except the number of base stations are increased from 6 to 8 stations.

The MS has a pseudo round random trajectory along 6 BSs located in a heterogeneous way. The application flow is still a 64kb streaming download from an application server.

IV. PERFORMANCE ANALYSIS

Various experiments are conducted to find the optimized values of MS speed, Scan threshold, Modulation & Coding and Antenna gain. One such optimized result is considered for our proposed system and the performance improvement is shown in terms of throughput.

A. Existing System

The Figure 3 and 4 shows that when the speed increases, with the MS moving on a linear trajectory along BS0 to BS5, the HO actions are (naturally) more frequent, and the instantaneous throughput has more gaps (this is very bad for real time applications because the duration of a gap is ~1-20 sec.).

Consequently, the average throughput - see the values at the end of simulation time (60 min) - decreases from ~52kBps to ~42kBps, i.e., with ~20%.

However, the performance is not satisfactory; the question is: could the HHO for such a case and given environment be somehow optimized if we selected some parameters of HHO algorithms thus as to be more adapted to the conditions? The answer is yes, as the following results will show.

B. Proposed System

We propose to optimize the decision taking algorithm parameters Modulation/coding, Scanning Threshold and Base Station & Mobile Station Antenna gain. The scanning activity is performed when the SNR is below 54dB (high value); consequently, the HO decides whenever a better SNR is observed, to switch to another BS than the serving one. For the current set of parameters, the overlapping area of the transmitting region is rather high. At each HO an initial ranging activity is performed. The cross-layer optimization of this configuration could be done if the scanning threshold were lower and consequently the HO decision taking less frequent, given a sufficiently high SNR from BS0 when MS is moving away from BS0. Antenna gains of the MS and BS are reduced to 1dBi and 8dBi respectively, in comparison to 14dBi and 15dBi. Adaptive Modulation and coding is used.

The SNR and HO(BS Index) show that a HO action is performed at a relatively high value of SNR, simply because the scanning threshold (ScTh) is rather high, the scanning activity is started “early” and the overlapping areas of the transmitting BSs are high enough, while the hysteresis threshold is low (0.4dB). Taking advantage of the fact that the SNR offered by BS0 is still rather high while the MS is not so far away from BS0, a simple idea would be to reduce the ScTh, as the MS would not care about the presence of other

BSs as long as it still gets a good enough SNR from BS0.

Figure 3 and 4 show that at ScTh =27 dB, for the same time same interval as in no HO is performed. For this time interval (60 min) the only serving BS is BS0 and no scanning is triggered (SNR is sufficiently high). Drop is decreased in application throughput is observed (as expected).

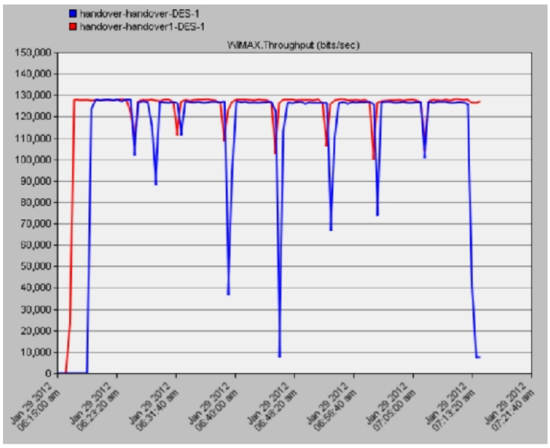

Fig. 3 WiMAX throughput

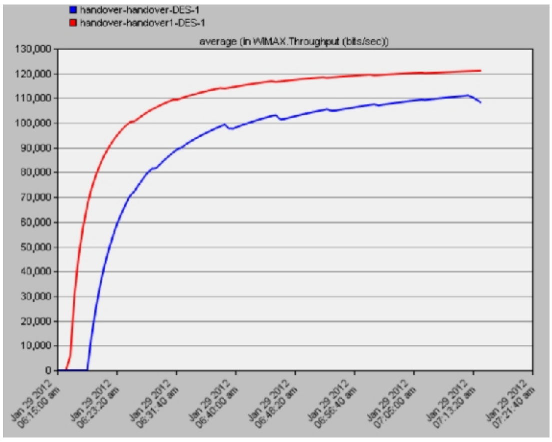

Fig. 4. Average in WiMAX throughput

This shows clearly that in the given conditions, the HHO should not be done in such a “hurry”, because the SNR offered by BS0 is still sufficiently high.

Other similar simulation runs, varying the ScTh values and hysteresis threshold offered the necessary data to allow the optimization of the HO for different speeds, while other parameters are invariant. Figure 3 and 4 shows that at lower values for the scanning threshold (and consequently for the trigger threshold) one can get a better mean throughput than for higher values. Therefore cross-layer optimization, based on sets of such values, can increase the performance.

V. CONCLUSION

This paper presents the simulation campaign done to identify the sets of configuration parameters in the IEEE 802.16e mobile station, in order to improve the cross-layer optimization decision-taking algorithms, applied during scanning and hard handover activities. Such quantitative results, collected for different combinations of parameters, can serve to offer guidelines for cross-layer optimization.

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