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Optimizing Channel Scanning during IEEE 802.16e Handover

P.P. Edwin Winston [1+] and Dr. K.S. Shaji [2]

[1] Department of ETCE, Sathyabama University

[2] Principal, RIITW

Abstract. Devised as a truly broadband access solution, the WiMAX technology offers promising features in terms of high bandwidth, extended coverage area and low cost. Similar to the different cellular and broadband technologies, global mobility related research in WiMAX is mostly focused on handover (HO) management. The WiMAX standard specifies a highly flexible and scalable layer 2 (MAC-layer) handover policy, allowing handovers to be initiated and optimized by the mobile station (MS), the Base Station (BS) or the backbone network. The existing WiMAX handover mechanisms suffer from certain drawbacks, particularly related to wastage of channel resources, handover latencies and loss of data. The IEEE 802.16e provides neighboring BS scanning opportunity before HO initiation. Since it is done before the actual HO, data transmission is not paused but interleaved with neighboring BS scanning. However, system throughput is degraded because they share the same wireless resources. A long scanning interval increases the packet jitter and the end-to-end delay, thus imposing large buffer sizes. On the other hand, a short scanning interval requires multiple iterations, thus increasing the overall scanning duration. We propose a scanning algorithm to optimize the scanning parameters such as Scan duration, Interleaving Interval and Scan Iterations for different MS speeds and BS densities. We have created a Handover scenario in OPNET MODELER and the performance is evaluated.

Keywords: WiMAX; Handover; Scanning; OPNET;

1. Introduction

Despite the challenges faced when transmitting data through varying wireless channels, broadband metropolitan area networks are becoming a reality. This is made possible by theoretical advances and also by improvements in technology that have led to faster and cheaper implementations. Though the existing Wireless Local Area Network (WLAN) and third generation (3G) technologies have been successfully providing broadband access for the last several years, they have their specific drawbacks, inhibiting their full-fledged growth. Devised as a truly broadband access solution, the WiMAX technology offers promising features in terms of high bandwidth, extended coverage area and low cost. This has led to its rapid rise as one of the most popular last mile broadband access technologies and as a likely component in future 4G networks. Similar to the different cellular and broadband technologies, global mobility related research in WiMAX is mostly focused on handover management. Handover management deals with the active transfer of wireless terminals from the control of a BS in one cell to the control of another BS in a different cell. The existing WiMAX mobility structure defines three types of link layer handover procedures in a homogeneous environment. Of these, Hard Handover (HHO) is the default handover mechanism and two soft handover mechanisms, Macro-Diversity Handover (MDHO) and Fast Base Station Switching (FBSS), are the optional procedures. The standard specifies a highly flexible and scalable layer 2 (MAC-layer) handover policy, allowing handovers to be initiated and optimized by the mobile station (MS), the BS or the backbone network.

[+] + P.P Edwin Winston. Tel.: + 917598532070.
E-mail address: edwinwinston@yahoo.co.in.

The existing WiMAX handover mechanisms suffer from certain drawbacks, particularly related to wastage of channel resources, handover latencies and loss of data. several mobility and handover related research issues must be resolved before the potential of WiMAX is realized. The global Telecommunication sector is quite positive that WiMAX technology has the potential to achieve this performance.

To provide stable handover (HO), the IEEE 802.16e BWA defines several steps of HO [1]. Before HO initiation, network topology acquisition including network topology advertisement, neighboring base station (BS) scanning, and the target BS association are carried out helped by backbone network. Then, cell reselection, HO decision, HO initiation, downlink synchronization with the target BS, initial ranging, termination service with the serving BS, authorization, and registration are performed during the actual HO. Unnecessary neighboring BS scanning and association are conducted before and during HO process. Once HO process is initiated, data transmission is paused until the establishment of the new connection. It causes service disruption for some time. Thus, the IEEE 802.16e provides neighboring BS scanning opportunity before HO initiation. Since it is done before the actual HO, data transmission is not paused but interleaved with neighboring BS scanning. However, system throughput is degraded because they share the same wireless resources. It is evident that determining the duration and frequency of channel scanning will have a direct impact on the application traffic and the resulting quality of service supported. A long scanning interval increases the packet jitter and the end-to-end delay, thus imposing large buffer sizes. On the other hand, a short scanning interval requires multiple iterations, thus increasing the overall scanning duration. Related work in the literature to date has mostly focused on reducing the number of MSs that need to perform channel scanning [2] [3]. We propose a scanning algorithm to optimize the scanning parameters such as Scan duration, Interleaving Interval and Scan Iterations for different MS speeds and BS densities. We have created a Handover scenario in OPNET MODELER and the performance is evaluated.

2. Network Topology Acquisition Phase

During the NTAP, the MS and serving BS (SBS), together with the help of the backhaul network, gather information about the underlying network topology before the actual handover decision is made. This is done to identify lists of potential NBSs, out of which one particular TBS may be chosen for the handover activity. Figure 1 shows the message sequence chart for the procedure. The major tasks involved in this phase are briefly as follows:

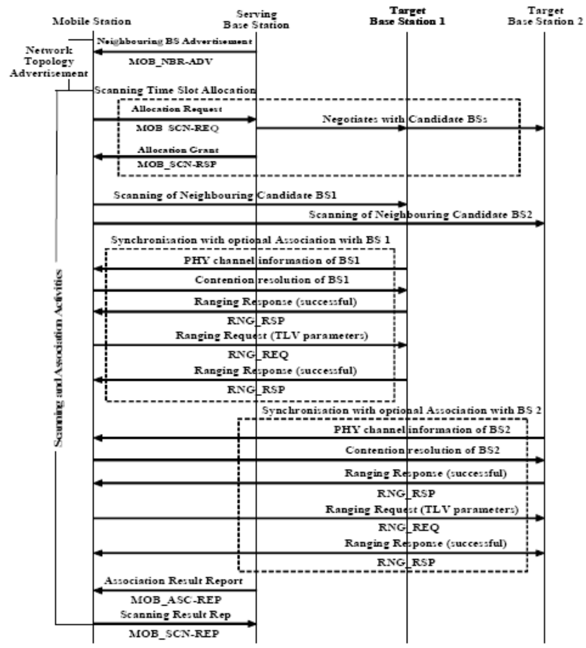

Fig. 1: NTAP

• BS advertises the Network Topology: Using MOB NBRADV (Mobile Neighbour Advertisement) message, the SBS periodically broadcasts information about the state of the NBSs, preparing for potential handover activities. The SBS keeps on gathering these channel information of the NBSs with the help of the backbone network.

• Scanning of advertised neighbouring BSs by MS: The MS scans the advertised BSs within specific time frames, to select suitable candidate BSs for the handover. A list of potential candidate TBSs is thus maintained. This procedure is carried out with the help of Scanning Interval Allocation request and response messages (MOB SCN-REQ and MOB SCN-RSP), respectively, sent by the MS and the SBS. In the end, Scanning Result Report (MOB SCN-REP) summarizes all the scanning activities.

• Ranging and Optional Association Activities: The scanning is followed by contention/non-contention ranging activities through which the MS gathers further information about the PHY channel related to the selected TBSs. Ranging Request (RNG REQ) and Ranging Response (RNG RSP) messages are used for this purpose. Ranging may be followed by optional association activities through which the MS gets associated with the potential target BS candidates. Association Result Reports (MOB ASC-REP) are used for this purpose.

3. Channel Scanning

Scanning of multiple channels is an inevitable activity for discovering the NBS that is most suitable to be the potential TBS. The scanning procedure in the IEEE 802.16e protocol is designed as a periodical scanning process. Typically scanning procedures are conducted within the overlapping area of two BS. The 802.16e extension to the standard defines several mechanisms related to BS communication and channel scanning in order to facilitate neighbor discovery and handovers. Regarding BS communication, the assumption in IEEE 802.16e is that neighboring BSs exchange downlink and uplink channel descriptors (DCD and UCD messages) over the backbone. The information is then embedded in messages sent periodically by the serving BS to the MSs. This allows an MS to acquire channel information prior to any scanning. Mechanisms related to channel scanning are in the form of requests sent by the MS seeking to maintain information about neighboring BSs.

When the fading SNR reaches the scanning threshold the SS 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 management-message 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 a 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 is meaningful in order 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 . This coordination between the MS and the BS allows each entity to buffer packets while the communication is temporarily suspended. At the end of the scanning, the MS reports the scan status to its serving BS in the form of a MOB-SCN REP message.

These scanning intervals are allocated by the SBS dynamically on getting scanning interval allocation requests from the MS. However, frequent temporary suspension of data exchange lowers the system throughput, and adds more delay to the overall handover process. Also, QoS requirements may get disrupted owing to this. Moreover, during scanning intervals, all data meant for the MS are buffered at the SBS, what leads to wastage of channel resources. Hence, it is desirable to devise techniques of effective estimation and minimisation of both the frequency and the time interval needed for scanning. Required also are the methodologies to carrying out scanning and data exchange concurrently. It should be noted that, as the QoS might get hampered in case of both long and short scanning intervals, optimization of scanning intervals is an important issue.

An efficient Adaptive Channel Scanning algorithm in a multi-MS oriented MWiMAX environment, relying on the exchange of configuration parameters between the NBSs in order to find out the required scanning time for a MS, is proposed in [5]. Along with optimization of the allocated scanning intervals for all MSs, the scheme also maintains the QoS of the application traffic in the system. However, utilization of unlimited channel buffers, in order to make the packet loss almost negligible, complicates the problem of channel resource wastage. Another proposal, for minimizing the influence of scanning intervals by concurrent scanning and data transmission by the MS is discussed in [6]. This fast synchronization and association model uses the unique IDs of the SBS and the NBSs (unique BSIDs), to distinguish between the UL/DL messages of the SBS and the NBSs. As the MS can clearly identify and separate the SBS's data exchange messages from the NBSs' synchronization and association messages, it can communicate with both of them at the same time, with the ranging slots appropriately adjusted by the SBS to minimize the chances of collisions. This scheme, however, neither considers a multi-MS environment nor considers an environment where the different NBSs and the SBS might not be controlled by the same service provider network [5]. An MS's sleep mode option [7] also provides an interesting mechanism for the MS to perform scanning without hampering the communication with the SBS.

4. Proposed Channel Scanning

The main objective of the proposed algorithm is to optimize the scanning parameters such as Scan duration, Interleaving Interval and Scan Iterations. Scan Duration is the Time (in frames) the Mobile Station(MS) scans/measures the neighbor BSs. Measurements are use to evaluate which Base Station(BS) is the best candidate to handover. Interleaving Interval is the Duration (in frames) or normal operation intervals (interleaving intervals) during the scanning mode of a Mobile Station. Scan Iterations is Number of repetitions of scan interval and interleaving interval during the scanning mode of a Mobile Station. We have experimented different sets the optimized values for the three parameters namely Scan duration, Interleaving Interval and Scan Iterations. The experiment considers speed of the mobile station and the density of the Base stations available for the particular MS at a given point. All the parameters considered have three values namely LOW, MEDIUM and HIGH.

The table 1 below shows the values for LOW, MEDIUM and HIGH for all the parameters.

Parameters	LOW	MEDIUM	HIGH
Scan duration	10	20	30
Interleaving Interval	50	150	250
Scan Iterations	5	10	15
MS speed (kmph)	10	60	100
BS Density	1	2-3	4

Table 1

Scan Method	Scan Duration	Interleaving Interval	Scan Iterations
S1	30	50	10
S2	30	50	15
S3	30	50	5
S4	20	150	10
S5	20	150	15
S6	20	150	5
S7	10	250	10
S8	10	250	15
S9	10	250	5

Table 2

5. Scanning Performance

To evaluate the performance of the optimization parameters we considered nine scenarios (Table 2) each for 10 kmph speed and 100 kmph speed. Low BS Density and High BS Density are also considered. The MS scan threshold was fixed to 54dB. It is seen that S1 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, S9 has small N/P, i.e. the scanning relative time is less than the time spent for data transmission.

It is seen that for low BS density the scanning method is not so critical, therefore, a light scanning (small N/P) is sufficient to allow more relative time for data transmission. However, a dense scanning method is very effective for high density, when mobile is quickly aware about the next BS available, and the low scanning method implies a slow reaction of mobile to communication condition changes. Figure 2, 3 shows the throughput and delay respectively for low BS density in the range experimented.

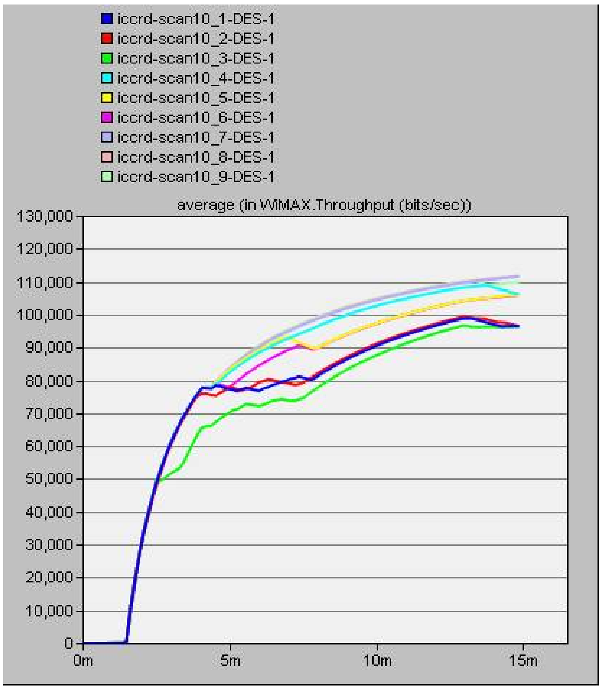

Fig. 2: Throughput

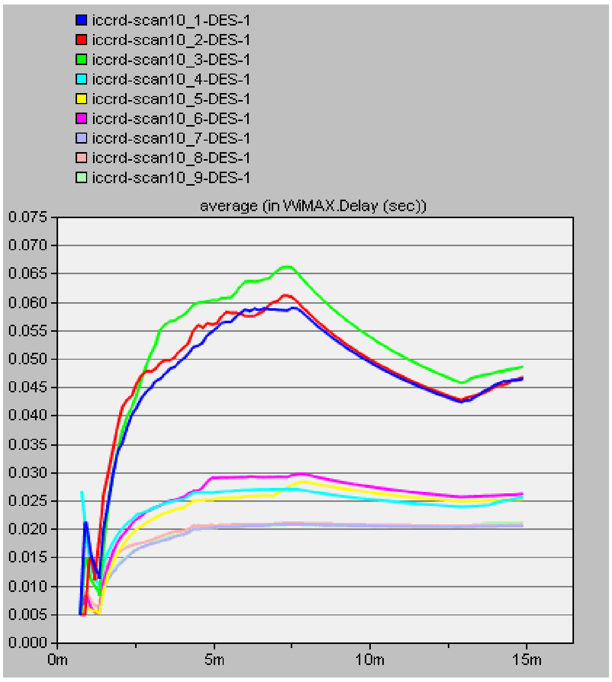

Fig. 3: Delay

6. Conclusion

The effect of different scan durations and frame durations on the L2-handover delay for Mobile WiMAX has been shown in this paper. The handover processing delays depend linearly on the configured frame duration and amount of channels in the system. The introduction of optimization parameters during the scanning process leads to shorter overall handover delays due to the higher reliability of the measurements. 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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