

# The Analysis of Scanning Time in IEEE802.16m's Handover Procedure

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**Abstract**—In this paper we analyze the efficiency of scanning process on handover procedure in IEEE802.16m. Since the .16m is still under development, the performance evaluation is based on current running standard of 802.16e. We consider four scan types and evaluate the average scanning time required. In addition, four different handover strategies are utilized to analyze the handover interruption time. The evaluation is done at both parts of handover procedure i.e. network topology acquisition and handover process. The efficient scanning process is proposed to reduce the scanning time and obtained a minimal handover interruption time.

**Keywords**—component; WiMAX, handover, efficiency, MAC

## I. INTRODUCTION

The IEEE 802.16m amends the IEEE802.16 WirelessMAN-OFDMA specification to provide an advanced air interface for operation in licensed frequency bands. It includes enhancements and extensions to the IEEE 802.16e to meet the cellular layer requirements of International Mobile Telecommunication-Advanced (IMT-Advanced) next generation mobile networks conducted by The International Telecommunications Union – Radio Communications Sector (ITU-R) [1].

The handover is an integral part of all mobile wireless systems. Continuous connection during user movement among cells is allowed due to handover, but on the other hand, the handover brings a significant increase of Medium Access Control (MAC) overhead and also causes an increase in delay of packet delivery to the destination user.

The handover were introduced in the latest version of IEEE802.16e [2]. Based on the emerging 802.16j proposals, it is very probable that in the next versions of WiMAX recommendations (IEEE 802.16j, IEEE 802.16m) will be defined same types of handovers and also the general principles (with regards to the requirements of new standards) of handover will be adopted from 802.16e.

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principles (with regards to the requirements of new standards) of handover will be adopted from 802.16e

The handover issues on IEEE802.16 have been carried out in several literatures. The fast handover in IEEE802.16e is analyzed in [3] and [9]. The single neighbor BS scanning, fast ranging and pre-registration have been proposed to reduce the handover time. To decrease hard handover, the authors in [4] propose handover modification that makes possible to receive downlink data just after synchronization with downlink channel of the target Base Station (BS). This is achieved by introducing a new MAC management message – Fast DL\_MAP\_IE, which describes the fast downlink access definition in system's information element (IE). This message is used for transmission of emergent packet (packet with payload of delay sensitive services) by target BS to mobile station (MS). In [5], the collision of connection identifiers (CIDs) in the target BS is solved by employing transport CID mapping scheme that increases the handover performance. The authors also introduce *passport* handover to decrease the hard handover delay.

The aim of this paper is to analyse scanning time during the network topology acquisition stage of handover procedure and to determine handover interruption time that occurs during the handover procedure. We consider several scan types and several handover strategies in our analysis to obtain the most efficient scanning time and the lowest interruption time.

The remaining of the paper is organized as follows. The description of handover procedure based on IEEE802.16e standard, the analysis of inefficient aspect of handover, scanning time analysis and handover interruption time in IEEE802.16m's system profile are described in Section 2. The result analyses by numerical calculations are given in Section 3. Section 4 concludes our work and highlights our future work.

## II. HANDOVER PROCEDURE

### A. IEEE802.16e Handover

According to [2], the handover procedure can be divided in two stages (Figure 1). Stage that is executed before handover, called *Network Topology Acquisition*, contains network topology advertisement and MS scanning. In this stage, the Mobile Station (MS) investigates and collects information about neighborhood base stations of its Serving BS. During the

scanning phase, the MS seeks a suitable handover to the target BS or Relay Station (RS) that are suitable to be added to the Diversity Set. The Diversity Set is a list of the BSs/RSs, which are involved in the handover procedure in case of Macro Diversity Handover (MDHO) or Fast Base Station Switching (FBSS).

The scanning is prepared in the “scanning intervals” which interleave the normal operation of the MS. Once the scanning is completed, the MS sends results to the BS. The reported result can be delivered by two report types; the first one is “event trigger report”, in which MS sends reports based on a defined trigger i.e. CINR, Receive Signal Strength Indicator (RSSI), Relative delay, or Round Trip Delay (RTD). In this type of report, the measurement report is sent to the serving BS after each measurement case. In the second type, “periodic report”, the MS sends reports at periodic intervals.

The results of scanning are used in the next stage of handover procedure called **Handover Process**. The first step is *cell reselection*. In this step, the possible Target BS is selected based on signal levels and offered QoS. It is followed by the *handover decision and initiation* process which is started when all conditions and requirements for handover are met. The first step of handover process is ended by performing the synchronization to the new target BS downlink. However, before the synchronization is done the connections to the serving BS should be closed first.

As soon as the downlink synchronization is completed, the MS can start the next stage of handover with *network re-entry* procedure. Network re-entry consists of three substeps i.e. *ranging, re-authorization and re-registration*. In the ranging process the MS obtains information about uplink channel such as UL-MAP (Uplink MAP) and UCD (Uplink Channel Descriptor) messages. Ranging is followed by authorization and registration of MS to the target BS. After successful authorization and registration to the target BS, then the MS can start with normal operation.

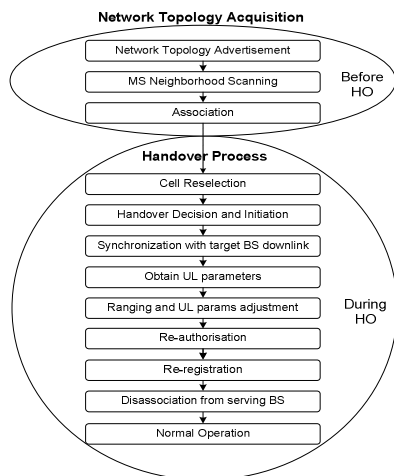


Figure 1. Two stages of Handover Procedure based on IEEE802.16e

## B. MAC Management Overhead in Handover

The total handover overhead come up in one handover procedure is given by the summarization of length of all handover MAC management messages exchanged during the handover procedure.

Generally, the total handover overhead generated is affected by the following parameters:

- Frequency of handovers (number of handovers per time interval)
- Sequence of exchanged messages during handover
- Length and structure of MAC messages

### Frequency of handovers

The number of handovers per a time interval depends on numbers of MSs and BSs/RSs, speed of MSs, the trajectory of MSs and the setting of cells’ boundary. The number of MSs and BSs/RSs in a network and speed of MSs are random and cannot be changed or influenced without impact on users QoS. In contrast, the boundary of cells (or range of BS’ areas) can be effected by network parameters setting (threshold levels, relative or absolute thresholds, hard handover threshold hysteresis, etc).

### Sequence of exchanged messages during handover

The sequence of management messages is different (but analogical) for all types of handovers and also can be different for the same types of handover but in different conditions or different handover requirements. Besides, the message sequence depends on the initiator of handover procedure (BS or MS). MAC management message sequence can be modified by the setting of the network parameters such as frequency of MS scanning for neighbourhood BSs and scanning results reporting.

### Length and structure of MAC messages

The length of most of MAC management messages vary based on the handover conditions, types and requirements, but they are exactly defined in standard [2]. The length of messages is affected by proper setting of the handover parameters (e.g. range of BSs cell, thresholds, etc.). For example, the length of messages depends on the number of recommended BSs to scan.

## C. Minimization of MAC Management Overhead

### 1) Reducing The Scanning Time

In network topology acquisition stage, in fact, there is only one BS that can be selected as target BS for handover. In addition, the result gained from the scanning process may become invalid because of the changing of neighbour BS’s channel quality. Consequently, if the scan or association process occupies too many resources, the throughput will significantly decrease. Furthermore, there is also uncertain scanning time since it is not clearly stated in the standard. If the scanning is not done with proper timing, channel condition of neighbouring BSs may be changed. That would make scanning process results useless. At last, the throughput is reduced since downlink data transmission is paused and interleaved when MS

conducted BSs scanning. Figure 2 shows the exchanges of MAC management message in the handover procedure.

These two parts of handover procedure that have been designed on MAC layer, have contribute to the overhead in 802.16. However, there are several schemes that can be implemented to cope these issues. The main waste of resources are caused by redundant scan and association process of neighbour BSs. Therefore, the single neighbour BS scanning scheme is proposed to resolved the issue.

The target BS estimation algorithm, in which MS only scan or associates to the neighbour BS with the best CINR is also proposed. Other proposed scheme is the use of fast ranging, where the target BS uses a Fast\_Ranging\_IE to grant a dedicated uplink ranging opportunity to MS in its broadcasting UL-MAP message. So, the MS does not need to do contention-based ranging. Finally, the pre-registration, in which target BS obtains the service flow and authentication information of this MS through backbone networks before handover, is deployed to reduce the overhead.

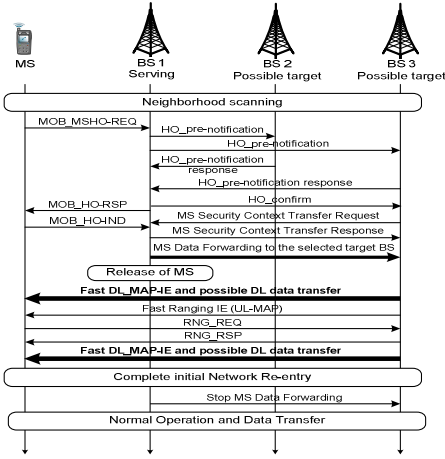


Figure 2. MAC Management Message exchanges within the handover

To analyze the performance of efficient scanning scheme, we consider four types of scanning. The first type is  $Scn_1$  which is defined as the scan process of BSs by MS without association. In this scan type, the MS is only requested to obtain downlink synchronization with the target BS in order to get information about the quality of target BS's physical channel. The  $Scn_1$  can be calculated as:

$$Scn_1 = n \times T_{Sync} \quad (1)$$

where  $n$  denotes as the number of neighbor BSs that need to be scanned.  $T_{Sync}$  is the average time required for downlink synchronization.

The second type is  $T_{Scn_2}$  that is defined as the scan of BSs by the MS without coordination. A MS requires the downlink synchronization as well as the execution a contention resolution-based ranging. The  $Scn_2$  is give by equation 2:

$$Scn_2 = n \times (T_{Sync} + T_{Cont\_res}) \quad (2)$$

where  $T_{Cont\_res}$  is defined as the average time required for contention resolution-based ranging (see equation 5 for the calculation).

The third type is  $Scn_3$  which is defined as the scan of BS by MS with coordination mode. The MS requires the downlink synchronization and the execution of a fast ranging process. The scanning time can be calculated as:

$$Scn_3 = n \times (T_{Sync} + T_{Rng}) \quad (3)$$

where  $T_{Rng}$  is average time required for fast ranging (see equation 6 for calculation).

The fourth type is  $Scn_4$  i.e. the scanning process of BS by MS with network assisted association reporting mode. It is similar to  $T_{Scn_3}$  however the difference is that the target BS does not send RNG-RSP message directly to the MS. RNG-RSP message is firstly sent to the serving BS through backbone networks. Then, the serving BS packs all RNG-RSP messages from scanned neighbor BSs into a MOB\_ASC-REPORT message and sends it to the MS either during interleave scanning intervals or normal operation time. Thus, the average time required for fast ranging is assumed to be a half of that for a contention-based ranging.  $Scn_4$  can be approximated as equation (4). More details concerning different type of scanning processes can be found in reference [3].

$$Scn_4 = n \times \left( T_{Sync} + \left[ \frac{1}{2} \times T_{Rng} \right] \right) \quad (4)$$

## 2) Performance Analysis of Scanning Time

Based on system description document, we assumed a 20 ms super frame of IEEE802.16m is divided into 4 equally-size frames, where the frame length is assumed to be 5 ms [8]. The ratio of cell load ( $R_{Load}$ ) is assumed to be  $0 \leq R_{Load} \leq 100\%$ .

The  $T_{Cont\_res}$  depends on the CINR and ratio of cell load. According to [9] the  $T_{Cont\_res}$  is set to 75 ms and 150 ms when the ratio of cell load is 0% and 50% respectively. Since the ranging collision probability is higher as ratio of cell load increases, then  $T_{Cont\_res}$  can be approximated as:

$$T_{Cont\_res} = 75 + ([150 \times R_{Load}] \times 2) \quad (5)$$

The average time required for fast ranging ( $T_{Rng}$ ) is also assumed to be directly proportional to the ratio of cell load. The  $T_{Rng}$  is set to 25 ms and 50 ms when the ration of cell load is 0% and 50% respectively [9]. It can be calculated as:

$$T_{Rng} = 25 + ([50 \times R_{Load}] \times 2) \quad (6)$$

The average time required for authorization ( $T_{Auth}$ ) is relatively longer than the other times since it is the time needed by target BS to obtain the authorization information of MS from the authorization server.  $T_{Auth}$  is assumed to be 150 ms [3]. Finally, the average time required for registration ( $T_{Reg}$ ) is assumed to be 2 frames. The considered values of delays in our paper are summarized in Table I.

The results of scanning time performance with respect to cell load and number of neighbour BSs are depicted in Figure 3 and Figure 4. The discussion of the results can be found on section 3.

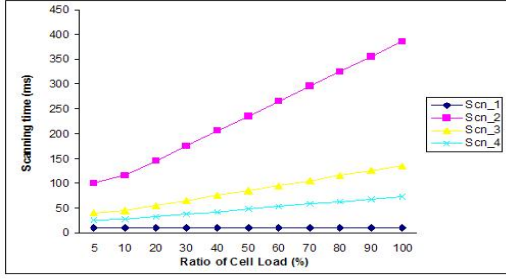


Figure 3. The scanning performance in various ratio of cell loads

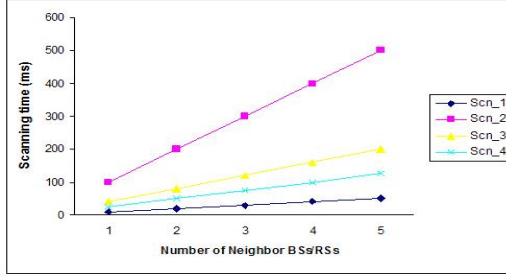


Figure 4. The scanning performance in various numbers of BS/RS

TABLE I. TIME PARAMATERS IN IEEE802.16M SCANNING PROCESS

Delay	Typical value
$T_{Sync}$	2 frames
$T_{Cont\_res}$	hunderdth of ms
$T_{Rng}$	tenth of ms
$T_{Auth}$	150 ms
$T_{Reg}$	2 frames

### 3) Handover Interruption Time

The handover interruption time in 802.16e systems is caused by switching of MS form the serving BS to the target BS. Although, the same description is assumed for 802.16m, however the system profile of 802.16m designed the maximum interruption time for handover i.e. 30 ms for intra-frequency and 100 ms for inter-frequency [6].

When the MS crosses a boarder of cells between the serving BS and target BS, the connection with the serving BS is closed. After that, a new connection with the target BS is established. Notice that after closing the connection and before setting up the new one, the MS has no connection to the network for a short time. During the interruption, packets must be routed from the serving BS to the target BS. After establishing of the connection between the MS and the target BS, packets are again sent to MS. The packets are delayed due to re-connection (network re-entry) of MS to the target BS [7].

The total interruption time on handover process depends on the handover strategy. The standard specifies four handover strategies as shown at Table II [2].

TABLE II. HANDOVER STRATEGY

Handover strategy	Description
<b>HO_1</b>	Handover with contention-based ranging
<b>HO_2</b>	Handover with fast ranging
<b>HO_3</b>	Handover with contention-based ranging and pre-registration
<b>HO_4</b>	Handover with fast ranging and pre-registration

In case of **HO\_1**, prior receiving HO-IND message with handover start or service release indicator, serving BS does not inform the target BS to provide dedicated ranging opportunity for MS. During the network re-entry, if collision occurs, MS executes random backoff algorithm and obtain a ranging opportunity through contention. Furthermore, the target BS does not obtain the MS's registration information such as authorization or service flow information from backbone network. Hence, the handover delay of **HO\_1** can be calculated as:

$$D_{HO\_1} = T_{Sync} + T_{Cont\_res} + T_{Auth} + T_{Reg} \quad (7)$$

The **HO\_2** includes the fast ranging phase, ,but the target BS does not obtain the MS's registration information from the backbone network. Therefore, the MS has to execute a re-authorization and re-registration process. The **HO\_2** handover delay can be calculated as:

$$D_{HO\_2} = T_{Sync} + T_{Rng} + T_{Auth} + T_{Reg} \quad (8)$$

In case of **HO\_3**, the contention-based ranging and pre-registration schemes are adopted. The target BS obtains the MS's registration information from the backbone network. Despite the target BS knows the MS's information, it requires to sent REQ-RSP message including CID updating information to the MS. Therefore the average time for pre-registration is assumed to be a half of the average time of whole registration process. The handover delay of **HO\_3** is given as:

$$D_{HO\_3} = T_{Sync} + T_{Cont\_res} + \frac{T_{Reg}}{2} \quad (9)$$

The last type of handover, **HO\_4**, adopts the fast ranging and pre-registration schemes. The target BS provides a dedicated ranging opportunity to MS and obtaining the service flow and authorization information of the MS from backbone network. The target BS also requires to send REQ-RSP message including CID update information the MS. Thus, the average time required for registration is assumed to be half of complete registration. The handover delay of **HO-4** can be calculated as:

$$D_{HO\_4} = T_{Sync} + T_{Rng} + \frac{T_{Reg}}{2} \quad (10)$$

The results of handover interruption time of four handover strategies are shown in Figure 5. The results are discussed in section 3.

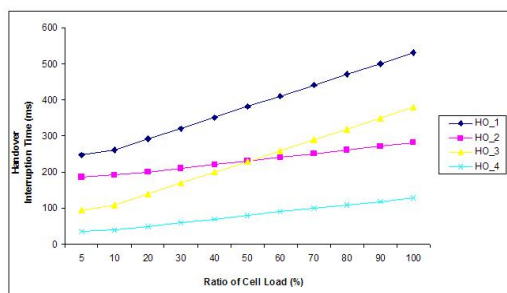


Figure 5. Handover interruption time in various handover strategies

### III. EFFICIENCY ANALYSIS

Based on results shown on the previous section, in this section we present the description of efficiency analysis of scanning process and handover interruption time.

According to Figure 3, it can be observed that the ratio of cell load has significant impact on scanning time for some scan types. In case of scanning without association ( $T_{Scn_1}$ ) the scanning time remain the same when ratio of cell load increases. This is due to the fact that a MS only needs to perform downlink synchronization with the target BS to get the quality information of its physical channel. For others scan mechanism, the scan time increases as the cell load increases.

In Figure 4, it can be seen that number of neighbor BSs affect the scanning time. For the ratio of cell load of 5%, and 5 neighbor BSs, the increase of scanning time is almost linear to the increase of number of neighbor BSs. The scanning without association ( $T_{Scn_1}$ ) also has a better performance than others scan type in this circumstance.

Figure 5 shows that the performance of handover interruption time depends on several conditions such as the ratio of cell load and frame duration. Handover with fast ranging and pre-registration ( $HO_4$ ) seems the only handover strategy that can fulfilled the IEEE802.16m's requirement since it can reach approximately 34 ms of the interruption time. It is also interesting to be considered that the handover strategies  $HO_1$  and  $HO_2$ , which contain the authorization process, have the higher interruption time.

The following Figure 6 shows the impact of frame duration of the scanning process. As it can be observed, the longer duration of the frame affect the scanning time linearly. Again, the scan type  $Scn_1$  shows the better performance since it has the lowest scanning time (10 ms).

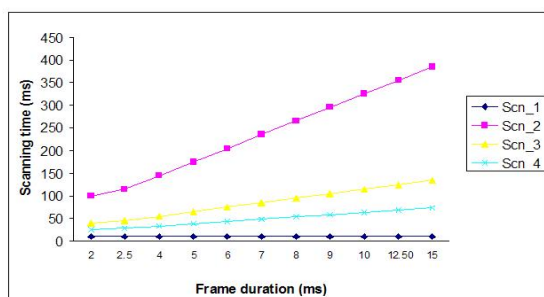


Figure 6. The effect of frame duration on the scanning time

### IV. CONCLUSIONS

This paper presents the efficiency performance analysis on handover's scanning process of IEEE802.16m. Since the standard is still under development, we assumed it has the similar handover procedure as described in IEEE802.16e. However, we included the 802.16m's system profiles in analysis. We concern on scanning time and handover interruption time as efficiency aspects. Based on our analysis, there are some inefficient issues in 802.16e's handover procedure which is critical for 802.16m. Those are the redundant scan and association process of neighbor BSs. In addition, the defined handover strategies also provide the overhead in handover procedure. It can be concluded that the BS scan without association is potential to be adopted since it has the lowest scanning time. In addition, the handover with fast ranging and pre-registration is favorable since it has the lowest interruption time.

The IEEE802.16m standard is designed to support high speed mobility therefore the handovers procedures can be expected to very frequently occur. Thus, the scanning process plays an important role in the handover procedure. In our future work, we would like to investigate the single BS scanning and avoiding the inefficient handover by means of mobility prediction.

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