ENHANCED HANDOVER MECHANISM FOR MULTICAST AND BROADCAST SERVICES IN IEEE 802.16E SYSTEMS

Min-Gon Kim
Public and Original Technology Research Center, Daegu Gyeongbuk Institute of Science and Technology (DGIST)
Daegu, Korea

Yazan M. Allawi
Department of Information and Communications Engineering, Korea Advanced Institute of Science and Technolog (KAIST)
Daejeon, Korea

Jung-Sook Jang, Jin-Kyu Kang, SangCheol Lee
Public and Original Technology Research Center, Daegu Gyeongbuk Institute of Science and Technology (DGIST)
Daegu, Korea

Minho Kang
Department of Electrical Engineering, Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea

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Abstract: The handover delay time spent in the service connections running at a Mobile Station (MS) in IEEE 802.16e systems can have a negative impact on real-time applications; especially, a connection for Multicast and Broadcast Service (MBS) could suffer additional handover delays due to multicast session update (the process of updating its associated MBS zone), where its MS moves out of its associated MBS zone. Taking this issue into account, this paper proposes an Enhanced Handover Mechanism (EHM) that can create the reduction of both the required time to scan neighbor Base Stations (BSs) and the number of the MBS session update by firstly selecting a neighbor BS guaranteeing a satisfactory level of Received Signal Strength (RSS) value in the current associated MBS zone as the target BS as many as possible. Simulation results show that the EHM can create the reduction of the handover delay time of both multicast and unicast connections while maintaining a satisfactory RSS value of an MS. As a consequence, enhancement of mobility support for real-time MBS can be achieved while keeping compatibility to IEEE 802.16e systems.

1 INTRODUCTION

One of the major goals of mobile WiMAX (IEEE 802.16e) (1) is to introduce mobility in WiMAX (2), based upon handover. The motivation of handover process is to consider the situation that Mobile Stations (MSs) move out of cell coverage of the current serving Base Station (BS); specifically, it aims to keep seamless service to MSs regardless of their locations. The handover process is initiated when Received Signal Strength (RSS) of an MS from the current serving BS is degraded due to high Bit Error Rate (BER), increasing distance between the MS and the serving BS, and out of the cell coverage of the serving BS to support services (3)(4). Throughout the handover process, the connection update to the target BS causes an inevitable delay time spent to sustain the service connections running at an MS, and thus it can have a negative impact on Urgent Grant Service (UGS), real time-Polling Service (rtPS), and Extend Real Time-Polling Service (ert-PS), which support delay-sensitive applications (e.g., Video on Demand (VoD) and Voice over IP (VoIP)) in IEEE 802.16e

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systems. Therefore, it is imperative to put into consideration the reduction of the initiation phase time during handover process.

Basically, when the RSS of an MS from the current serving BS is lower than the handover threshold value (a predefined value in the Medium Access Control (MAC) layer), the MS will try to find a target BS available in its vicinity by scanning every neighbor BS (cell reselection). Depending on the number of the scanned neighbor BSs, the required time to scan neighbor BSs is differently presented (5). Thus, there have been much effort on this aspect, the reduction of Layer 2 (L2) handover preparation delay (5)-(8). In addition, some studies for fast handover execution have been conducted (9)-(11). As another layer study, L3 handover mechanisms have tried to accelerate the L3 handover for mobile IPv6 (12)(15). However, the aforementioned studies have just tried to reduce L2 and L3 handover delay without concerning about additional handover delays from multicast session update (the process of updating its associated Multicast and Broadcast Service (MBS) zone in cases when inter-MBS zone handover is required).

Since MBS zone supports its application based upon Multicast Connection Identifier (MCID) (11), the multicast session update is for making the current serving BS join its associated MBS zone, where the MS moves out of its current MBS zone. To the best of our knowledge, there is no study on the aspect of reducing the inter-MBS zone handover delay. To reach a comprehensive understanding on this issue, this paper proposes an Enhanced Handover Mechanism (EHM), which considers the reduction of both the required time to scan neighbor BSs and the number of the MBS session updates by firstly selecting a neighbor BS guaranteeing a satisfactory level of RSS value in the current MBS zone as the target BS as many as possible. The scanning process to check the RSSs of the MS from neighbor BSs is continued until finding the BS included in Class H+ for the reduction of scanning time (this process adopts the First Satisfaction First Reservation (FSFR) concept (16)). Simulation results highlight the fact that the proposed mechanism can induce the reduction of the handover delay time regarding both multicast and unicast connections except the worst case that a full scanning process and an MBS session update occur while maintaining a satisfactory level of RSS of an MS.

2 OVERVIEW OF IEEE 802.16E HANDOVER PROCESS

2.1 Intra-MBS Zone Handover Process

Fundamentally, the serving BS periodically sends a neighbor advertisement (MOB-NBR-ADV) message to its associated MSs at a periodic interval (MOB-NBR-ADV interval (1)), where the MSs extract information about neighbor BSs such as the BS ID, radiation power, frequency assignment, and whether the BS is co-located with the serving BS transmitting this message, the scheduling service supported (e.g., UGS, rtPS, non-real time-Polling Service (nrtPS), and Best Effort (BE)), mobility and handover support, their UCD and DCD information. The MOB-NBR-ADV message information, which are structured and saved by each MS in a list, facilitates faster handover process from the serving BS to the target BS among these BSs.

Once an MS recognizes neighbor BSs and the current RSS from the serving BS is smaller than the handover threshold, the MS can start a scanning and association procedure in order to select a final target BS. The scanning procedure is conducted through exchanging scanning request (MOB-SCAN-REQ) and scanning response (MOB-SCAN-RSP) messages with the serving BS. Then, the serving BS will schedule scanning intervals or sleep intervals to the MS for scanning without terminating the current connection of the MS to the serving BS. Specifically, during the scanning process, all DL and UL transmissions are temporarily paused and the MS can optionally perform an association with neighbor BSs by performing an initial ranging handshaking. The aim of the association procedure is to enable the MS to acquire and record ranging parameters and service availability information for the purpose of selecting a target BS. If the MS decides to skip the association procedure, it must perform an initial ranging procedure with the target BS.

Based on the information from the scanning process, an initiation of handover process for a target BS is decided according to some criterions (not defined in the standard and left open to different implementations). Therefore, the handover process can be initiated by any of the MS, the serving BS or its associated network with either an MS handover request (MOB-MSHO-REQ) message or a BS handover request (MOB-BSHO-REQ) message, including the information of a target BS.

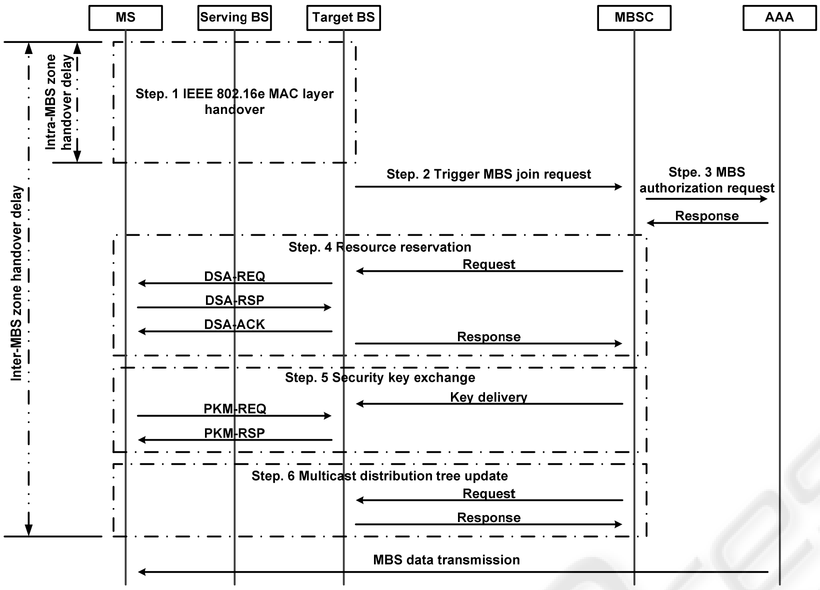

Figure 1: Multicast Broadcast Service (MBS) zone handover process for session update.

As the corresponding acknowledgement message of a handover request, a handover response message (e.g., MOB-MSHO-RSP or MOB-BSHO-RSP) is transferred to the MS by the serving BS and then a handover process is triggered through the MS's sending a handover indication (MOB-HO-IND) message to the serving BS. To smooth the progress of the handover process, the MS synchronizes to downlink transmissions of the target BS and obtain DL and UL transmissions parameters. Through the synchronized link, the MS and the target BS conduct handover ranging. If whole handover process is conducted successfully, MS context is terminated; otherwise, the MS cancels handover at any time prior to expiration of Resource-Retain-Time interval after transmitting an MOB-HO-IND message. Therefore, L2 handover delay (D_{HO}^{L2}) consists of scanning neighbor BSs (T_{SC}), synchronizing the MS to the target BS (T_{SYN}), contention resolution (T_{CR}), ranging (T_{RNG}), authentication and key exchange (T_{AUTH}^{L2}), and registration with the new serving BS (T_{REG}), as expressed by the following equation:

$$D^{L2}_{HO}=nT_{SC}+T_{SYN}+T_{CR}+T_{RNG}+T^{L2}_{AUTH}+T_{REG}, \quad (1)$$

where n is the number of neighbor BSs scanned. Therefore, the key issue of enhancing the L2 handover performance depends on the reduction of these factors effectively.

2.2 Inter-MBS Zone Handover Process

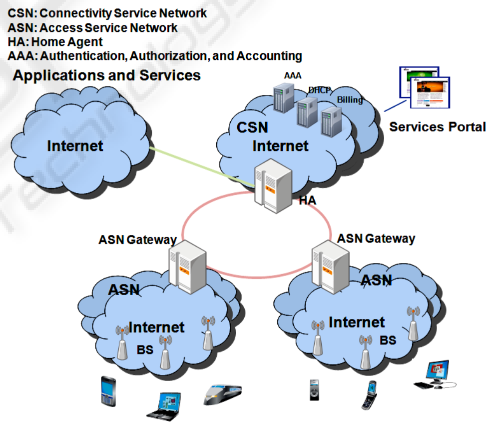

Figure 2: WiMAX networks for mobile operators.

Basically, IEEE 802.16e systems consist of three logical entities (e.g., Fig. 2): (i) *MS,* (ii) *Access Service Network (ASN),* and (iii) *Connectivity Service Network (CSN).* The serving BS performs radio-related functions in ASN, and the CSN performs IP connectivity services, administrative functions (e.g., Authentication, Authorization, and Accounting (AAA)), and admission control for WiMAX operators. To introduce an MBS in a IEEE 802.16e system, MBS Controller (MBSC) is included in CSN. An MBS session refers to a single multicast connection established between the MBSC and the MSs. The MBSC performs service provisioning and delivery functions for MBS and serves as an entry point for multimedia contents providers; i.e., when a new connection for multicast streaming services supporting multimedia contents is ready, the MBSC initiates the corresponding MBS connection by performing resource reservation for forwarding the multicast stream over the WiMAX networks. When handovers of multicast connections occur with the MBS session update, they consume additional handover delay times (11). That is to say, the handover delay of an MBS connection can suffer the intra-MBS zone handover delay or inter-MBS zone handover delay. In case of the intra-MBS zone handover where an MS with an MBS connection switches from the serving BS to the target BS in the MBS zone, only the IEEE 802.16e MAC layer handover delay is included in the delay (Step. 1 IEEE 802.16e MAC layer handover in Fig. 1). On the other hand, when it's imperative to perform inter-MBS zone handover, where an MS moves out of the current MBS zone, Steps 2 to 6 in Fig. 1 are included in the delay. Therefore, the MBS session update delay (D_{MBS}) is given by:

$$\begin{aligned} D_{MBS} = {} & (T_{TB\text{-}MBSC}+2T_{MBSC\text{-}AAA}+P^{MBS}{}_{AUTH}) \\ & + (2T_{TB\text{-}MBSC}+3T_{MS\text{-}TB}+P_{CONN}) \quad \ldots\ldots\ldots\ldots\ldots (2) \\ & + (T_{TB\text{-}MBSC}+2T_{MS\text{-}TB}+T_{KEY}) \\ & + (2T_{TB\text{-}MBSC}+P_{MUL}), \end{aligned}$$

where $T_{TB\text{-}MBCC}$ is the message transmission time between the target BS and MBSC, $T_{MBSC\text{-}AAA}$ is the message transmission time between MBSC and AAA, $P_{AUTH}{}^{MBS}$ is the processing time of MBSC authorization, P_{CONN} is the processing time to establish a multicast connection at an MS, $T_{MS\text{-}TB}$ is the message transmission time between an MS and the target BS, T_{KEY} is the processing time to set up a security key at an MS, and P_{MUL} is the processing time to perform a multicast distribution update at MBSC. Therefore, in order to enhance the delay performance of real-time multicast streaming services, there need to be considerations on methods for reducing MBS session updates.

3 ENHANCED HANDOVER MECHANISM (EHM)

To begin with, in order to transmit the information about MCIDs of neighbor BSs, MOB-NBR-ADV messages are observed and modified, as follows. Basically, BSs supporting mobile functionality are capable of transmitting a MOB-NBR-ADV message at a periodic interval to identify the network and define the characteristics of neighbor BS to potential MS seeking initial network entry or handover. The message contains the information of neighbor BSs regarding BSID (24 bits), frequency (8 bits), scheduling service supported (8 bits), and so on (1). Specifically, MCIDs supported by neighbor BSs can be transmitted to MSs by changing scheduling service supported field (8 bits) in the message to MCID field (1). For the downlink multicast service, the same MCID is assigned to all corresponding MSs on the same channel that participates in this connection. The MCID field is used for transmitting the information from 9 to 16 bits of MCID field (8 bits) to MSs. Even though MCID is 16 bits, MSs can get MCID information because MCID is 0xFEA0-0XFEFE (1) or 0xFEA0-0XFEFD (17). This implies that MCIDs can be recognized with the part of 9 to 16 bits.

Based upon the MCID obtained from a MOB-NBR-ADV message, The MS is capable of deciding the order for scanning neighbor BSs. As shown in Fig. 1 and described in Section 2, an initiation of intra-MBS zone handover delay is smaller than that of inter-MBS zone handover delay under the same condition. Therefore, the proposed mechanism, so called Enhanced Handover Mechanism (EHM), defines a neighbor BS having the same CIDs as the MCID supported by the MS as Class + (high class); otherwise, Class -. If RSS of the MS from the serving BS is smaller than the handover threshold value (i.e., handover occurs), the MS firstly scans the neighbor BSs in Class+ until finding a neighbor BS having a higher RSS than the (threshold + hysteresis) value (V_{bnd}) for guaranteeing a sufficient level of RSS of the MS and reducing the ping-pong effects. This BS is included in Class H+ and then it will be selected as the target BS. If there is a neighbor BS in Class H+, the scanning process will be stopped for adopting the merit of the FSFR mechanism (16). Otherwise (that is to say, there is no neighbor BS in Class H+), others in Class + are included in Class L+. Next, neighbor BSs in Class - are classified into Class H- or L- depending on their RSS value. As a result, Table I can be achieved. Then, with the order of Classes H-, L+, and L-, the EHM selects a BS having the greatest RSS in each class as the target BS. By doing so, the number of multicast session updates for real-time multicast streaming services can be kept as low as possible compared to the conventional handover mechanism with the aforementioned classification of the EHM. In addition, EHM considers the compatibility to

IEEE 802.16e systems, specifically regarding the MOB-NBR-ADV message format.

Algorithm 1 **The operation of the EHM (MS viewpoint)**

```
Require: V_bnd
while an MOB-NBR-ADV message is received do
    if multicast CIDs of neighbor BSIDs = that of the MS, then
        Define the neighbor BSID as class +.
    else
        Define the neighbor BSID as class -.
    end if
        if RSS of the MS to the serving BS < the handover threshold value then
            Scan BSs in class + until finding a BS having higher RSS than V_bnd.
            Define it as class H and others as class L.
            if class H+ list is not empty then
                Select the BS in class H+ as the target BS.
            else
                Scan BSs in class – until finding a BS having a higher RSS than V_bnd.
                Define it as class H and others as class L.
                if class L+ list is not empty then
                    Select a BS having the greatest RSS in class L+ as the target BS.
                else
                    Select a BS having the greatest RSS in class H- and L- as the target BS.
                end if
            end if
        end if
end while
```

4 PERFORMANCE EVALUATION

This section presents performance evaluation of the EHM compared to the conventional mechanism (Threshold-based Handover Mechanism (THM)), which selects a neighbor BS having the highest possible level of RSS when the RSS value received from the current serving BS become smaller than the handover threshold value. Simulation results are achieved under 1,000,000 seconds and obtained with the following assumptions: (i) there are 20 MSs, whose movements follow Random Walk mobility model (18), and 7BSs, which organize an octagon shape of a network, (ii) there are two types of connections in an MS (i.e., multicast and unicast connections without concerning about application and QoS type), (iii) all the necessary information involved in the handover process of the MS can be exchanged among the different BSs through the network backbone, and (iv) internal processing time of the MS is considered as negligible (i.e., the amount of time spent in constructing and traversing the short list of BSs is not included in the simulation results). Besides, the system specification parameters; the required times for IEEE 802.16e MAC layer handover, and the required times for MBS session update are defined as in Table II, III, and IV, respectively.

Table 2: System Parameters.

Symbol: Description	Value	Unit
P_{Tx}: Transmitter output power	64	W
PL_{FS}: Path loss	$35.4+35\log_{10} D_L$	dB
F_S: Shadow fading	None	-
$G_{Tx,A}$: Tx antenna gain	10	dBi
$G_{Rx,A}$: Rx antenna gain	0	dBi
N_{Tx}: Number of Tx antennas	1	-
N_{Rx}: Number of Rx antennas	1	-
S_{Rx}: Receiver sensitivity	-90	dBm
BW: Channel bandwidth	10^7	Hz
D_S: OFDM symbol duration	102.9	µs
T_S: Useful symbol time (87.5%)	91.4	µs
T_G: Guard time (12.5%)	11.4	µs
DL:UL ratio	28:9	-
P_{N0}: Noise power	-104	dBm
A_{tot}: Total evaluated area	100km*100km	-
U: Basic unit of area	100m*100m	-
A_{MIN}: Minimum position coordinates in A_{tot}	0	-
A_{MAX}: Maximum position coordinates in A_{tot}	1000	-
$SINR_H$: Requested SINR for handover	10	dB
$SINR_C$: Required SINR for coverage	8	dB

Table 3: Required times for MBS session update (11).

Symbol: Description	Value	Unit
T_{a-b}: Message transmission between a and b	5	ms
P_{AUTH}^{MBS}: MBS authorization at AAA	1	ms
P_{EST}: Establishing a multicast connection at an MS	1	ms
T_{KEY}: Setting up a security key at an MS	1	ms
P_{MUL}: Multicast distribution update at MBSC	1	ms

Table 4: Required times for L2 handover (17) (18).

Symbol: Description	Value	Unit
T_{SC}: Scanning a neighbor BS	5	ms
T_{SYN}: Synchronizing the MS to the target BS	10	ms
T_{CONT}^{RES}: Contention resolution	0 to 20	ms
T_{RNG}: Ranging	25	ms
T_{AUTH}^{L2}: Authentication and key exchange	25	ms
T_{REG}: Registration	10	ms

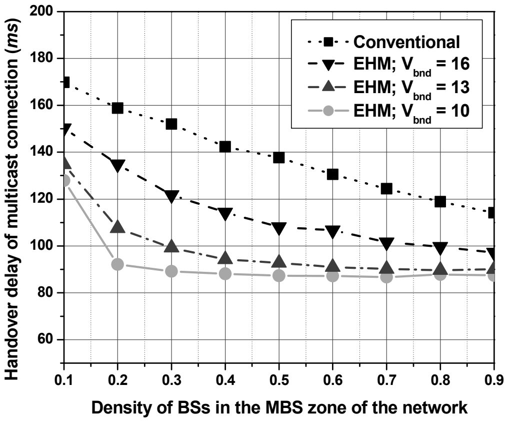

Figure 3: The average handover delay of multicast connection.

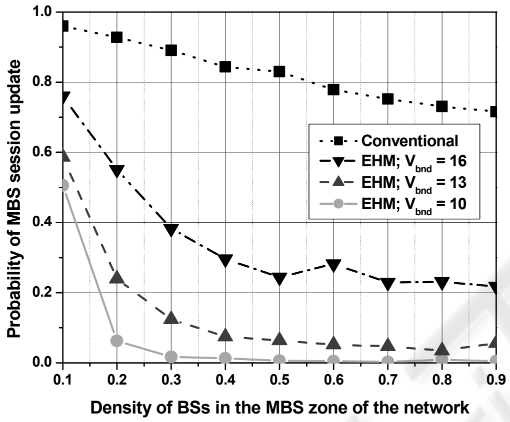

Figure 4: The probability of MBS session update.

Fig. 3 presents performance of the EHM compared to the conventional mechanism in terms of handover delay of multicast connection. Regardless of the density of BSs in the MBS zone of the network, the EHM effectively enhance the average handover delay of multicast connection. This achieved performance gain is mainly achieved by the reduced probability of MBS session update, as shown in Fig. 4, due to the defined classes, and partially done by the reducing the time required to scan neighbor BSs owing to the FSFR. As another positive effect of the EHM, Fig. 5 presents the average handover delay of unicast connection. There is a perceptible performance enhancement due to the FSFR concept, although it is not significant compared with the performance enhancement of multicast connection.

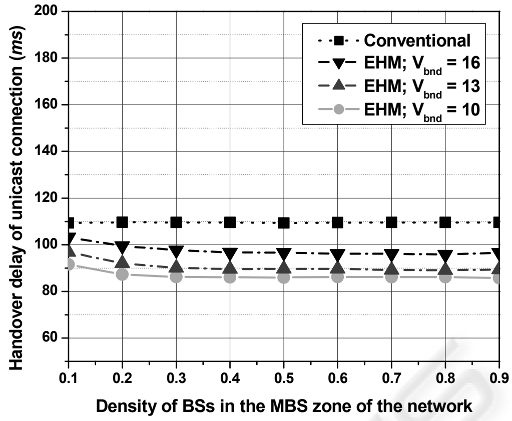

Figure 5: The average handover delay of unicast connection.

On the other hand, as a demerit of the EHM owing to the classification, shown in Fig. 6, a lower level of RSS values can be induced. The EHM, however, can keep a satisfactory level of RSS value for supporting applications. As presented in Figs. 3, 4, 5, and 6, the level of RSS value is controllable by setting a higher or lower values of V_{bnd} (e.g., a higher value of V_{bnd} cause a lower multicast connection handover delay and a higher RSS value, and vice versa). Thus, setting the value of V_{bnd} can depend on the requirements of the systems.

5 CONCLUSIONS

This paper proposed an EHM for real-time MBSs in IEEE 802.16e systems. Differing from the conventional mechanism, an MS under the EHM receives Multicast Connection IDentifier (MCID) information during neighbor advertisement from neighbor BSs, and thus it can extract the information of neighbor BSs regarding MBS. Then, the MS firstly selects the neighbor BS included in the same MBS zone and having a satisfactory level of RSS value for guaranteeing a sufficient link quality. The simulation results substantiate that the EHM can achieve better performance gain on the aspect of the multicast and unicast connections due to the proposed classification and the First Satisfactory First Reservation (FSFR). Consequently, MBSs, one of the most important services in IEEE 802.16e systems, can be well guaranteed with enhanced mobility management.

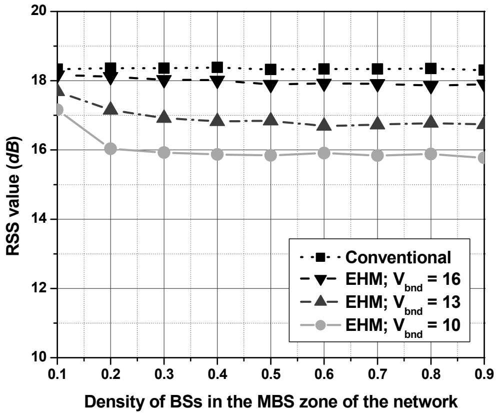

Figure 6: Performance of the EHM regarding the average RSS of MSs.

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