Optimization of Handover Scanning Procedure in WiMAX Networks with Relay Stations

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Abstract—**This paper proposes an optimization of management messages and their exchange during a scanning procedure of mobile station's neighborhood in WiMAX based networks with relay stations. The scanning procedure allows a mobile station to obtain information about handover target access stations. In IEEE 802.16e standard, where the relay stations are not considered, the exchange of requested information for handover execution is done among base stations and backbone network. When taking into account the relay stations, a new wireless interface among the base stations and relay stations emerged. Thus, a new communication scheme over the radio interface has to be proposed and optimized in order to reduce the management information overhead and to maximize the user data throughput.**

I. Introduction

According to the IEEE802.16e standard [1] the handover mechanism implemented in the WiMAX makes possible to support migration of Mobile Station (MS) from the air interface provided by one Base Station (BS) to the air interface provided by another BS. There are specified three types of handovers [2]: Hard Handover (HHO), Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS). While the HHO is mandatory in WiMAX systems, other two types of handover are optional. The MDHO and FBSS can be seen as soft handovers.

The IEEE802.16e standard defines a handover only among BSs, but it does not consider Relay Stations (RS). The RSs are generally simplified BSs and may be used either to extend coverage of a BS or to increase capacity in specific area [3]. There are two types of RSs: fixed and mobile. The fixed RS is permanently installed at the same place whereas the mobile RS is supposed to be implemented into moving vehicles (e.g. bus, train, etc.). The RSs are connected to the network via radio interface, i.e. there is no wired connection to the backbone. Two systems from relay capability point of view can be distinguished: centralized and decentralized relaying [4].

The implementation of RSs into WiMAX networks is the target of standard IEEE 802.16j [5] which is under specification.

The handover procedure can be decomposed into several phases [1]: Network topology advertisement, MS scanning, Cell Reselection, Handover decision and initiation, Handover execution and Termination. This paper focuses on the optimization of the MS scanning phase.

The rest of the paper is organized as follows. The next section describes the MS neighborhood scanning procedure in WiMAX according to the standard IEEE 802.16e and proposed optimization of the scanning procedure. Section III depicts evaluation of overhead. Simulation and results regarding the overhead are discussed in section IV. Conclusions and results are presented in the last section.

II. MS Scanning Procedure

If a MS is moving among BS's cells, it has to obtain information about BSs/RSs in MS's neighborhood to be prepared for switching from current serving BS/RS to new BS/RS that can provide better QoS (Quality of Services) to the MS. The MS has to seek a suitable neighbor BSs within a normal operation mode to fulfill handover. The procedure when a MS explores the neighborhood is called MS scanning.

A. MS scanning phase according to IEEE 802.16e

Time dedicated for the searching of BSs in the neighborhood is given by so-called scanning intervals. In these intervals, the MS determines the BS suitability to be a target BS for handover. The scanning intervals are allocated via MAC management messages (MOB_SCN-REQ and MOB_SCN-PSR). After the MS finishes the scanning of the neighboring BSs, the results are sent to the serving BS by means of MOB_SCN-REP (or MOB_SCN-RSP) message [1].

During the scanning phase, the MS can request association with a neighbor BS. The association enables the MS to obtain and to record ranging parameters and service availability concerning the eventual handover target stations. Acquired information is used during "Cell reselection" procedure for selection of target station. Reference [1] defines three types of association levels:

a) level 0: scan/association without coordination,
b) level 1: association with coordination,
c) level 2: network assisted association reporting.

The requested type of association is specified in MOB_SCN-REQ message, in a field called "scanning type".

The MS scanning process according to IEEE 802.16e is shown in Figure 1. The MS sent a request for allocation of scanning intervals (MOB_SCN-REQ) to the serving BS. If the scanning with association (or coordination) is required, serving BS should negotiate the association parameters with neighboring BSs. After negotiation, the serving BS sent requested information (including allocated scanning intervals) back to the MS in MOB_SCN-RSP message and MS can start with scanning of neighborhood. The scanning results are reported to serving BS in MOB_SCN-REP message (see [2]).

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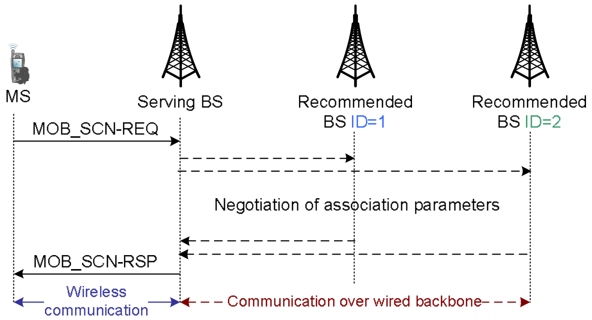

Figure 1. MAC management messages exchange during MS scanning with association according to IEEE 802.16e

B. *Proposed scanning procedure in networks with relays*

In case of scanning without the association and coordination, the procedure corresponds to the procedure specified in IEEE 802.16e. In case of association level 1 and level 2, the coordination of association over relay links has to be defined; the IEEE 802.16e only assumes the coordination over the backbone network.

One of possible MS scanning procedures with RSs support is proposed in [6] and [7]. The principle of this scanning procedure is shown in Figure 2. An access station (RS or BS) transmits a separated request message (ST_SCN-REQ) for coordination information to each recommended stations. These messages are forwarded to the recommended stations and they should respond through message ST_SCN-RSP.

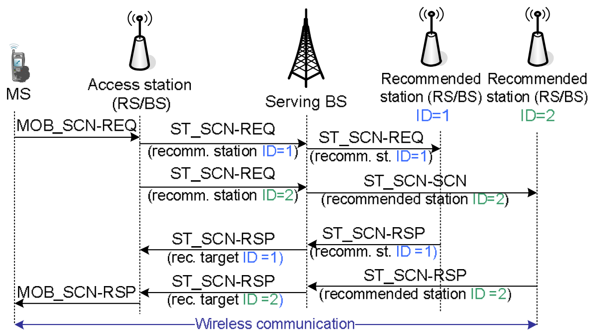

Figure 2. MAC management messages exchange during MS scanning procedure with association according to IEEE 802.16j proposal [6].

The structures of messages are presented in Table I and Table II.

TABLE I.
STRUCTURE OF ST_SCN–REQ MESSAGE

Syntax	Size (bites)	Notes
ST_SCN-REQ{		
Message type	8	
MS ID	48	
Access ID	48	
RcS_ID	48	
Scanning type	3	
}		
Padding	TBD	Padding to reach byte boundary
}		

TABLE II.
STRUCTURE OF ST_SCN–RSP MESSAGE

Syntax	Size (bites)	Notes
ST_SCN-RSP{		
Message type	8	
Recommended target St ID	48	
Current Access ID	48	
Associated MS ID	48	
Scanning type	3	
If (Scanning type>0) {		
Rendezvous Time	8	
CDMA code	8	
Transmission opportunity offset	8	
}		
Padding	TBD	Padding to byte
}		

Based on this proposal, we suggest modifications that can significantly decrease the MAC message overhead.

Proposed scanning procedure has a similar beginning to the procedure defined in [1]. The MS transmits the scanning request message MOB_SCN-REQ that contains: scanning and interleaving intervals, (requested by BS/RS station) and scanning types to the access station. If the access station is a RS, the request is forwarded in the direction of serving BS. Each subordinated RS knows the relay path to the serving BS. In cases of scanning without the association or scanning with association level 0 (without coordination), the serving BS responds with scanning response message MOB_SCN-RSP containing confirmation (or new definition) of requested intervals and list of BSs/RSs that will be scanned.

In case of scanning procedure for the association level 1 and level 2, the coordination of association over relay links has to be provided. The proposed scanning procedure is shown in Figure 3.

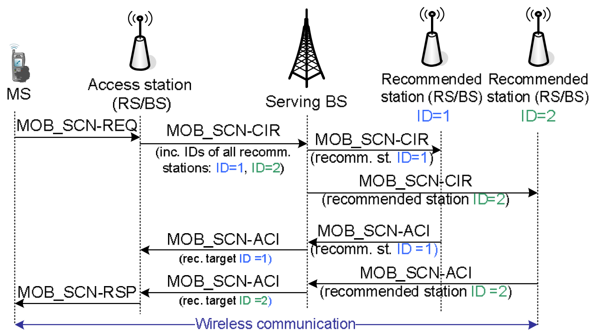

Figure 3. Proposed MAC management messages exchange during MS scanning procedure with association.

The access station (BS/RS) transmits a newly proposed message called MOB_SCN-CIR (coordination info request) to all recommended stations. The coordination info request (see Table III) contains identification of all recommended stations with scanning type=0b010 or 0b011. The request is routed to the serving BS. The serving BS creates an individual message for each recommended RSs with scanning type corresponding to the scanning with association level 1 or level 2. This message does not contain identification of recommended stations, but includes only identification of one recommended station. To each recommended station is sent just one request. Thus, the number of messages transmitted by BS to recommended stations corresponds with the number of recommended stations (N_RcS).

TABLE III.
STRUCTURE OF MOB_SCN–ACI MESSAGE

Syntax	Size (bites)	Notes
MOB_SCN-ACI{		
Message type	8	
MS ID	48	Identification of MS
Access ID	48	Identification of access station
RcS_ID	48	Identification of recommended target station (RS or BS)
Scanning type	3	0b000 and 0b001 – N/A 0b010 : scann. with assoc. level 1 0b011 : scann. with assoc. level 2
If (Scanning type>0) {		
Rendezvous Time	8	see [1]
CDMA code	8	see [1]
Transmission opportunity offset	8	see [1]
}		
Padding	5	
}		

Each recommended station with scanning type=0b010 or 0b011 answers by message MOB_SCN-ACI (scanning with association with coordination info, see Table IV) that contains parameters needed for the association.

TABLE IV.
STRUCTURE OF MOB_SCN–CIR MESSAGE

Syntax	Size (bites)	Notes
MOB_SCN-CIR{		
Message type	8	
MS ID	48	Identification of MS
Access ID	48	Identification of access station
N_ Rec_St	8	Number of recommended stations
For (i=0; i<N_ RcS; i++){		
RcS_ID	48	Identification of recommended target station (RS/BS)
Scanning type	3	0b000 and 0b001 – N/A 0b010 : scann. with assoc. level 1 0b011 : scann. with assoc. level 2
}		
Padding	5	
}		

If the coordination information request transmitted by the access station is routed via one of recommended station, the station can directly respond with MOB_SCN-ACI. In such situation, the recommended station has to remove its own ID and scanning type from the list of recommended stations and it has to decrease the parameter N_RcS by 1. If the parameter N_RcS is = 0, the request is not forwarded to the BS, since there is no more stations to be associated.

In our proposal, in comparison with the proposal in [6], the requested coordination information contains identification of all recommended targets to scan and individual messages are created in the serving BS.

III. OVERHEAD CALCULATION

The total overhead, due to the MS scanning can be divided into two parts: Uplink Overhead and Downlink Overhead.

A. Uplink overhead

The uplink overhead represents an overhead of messages that are sent from a MS to all recommended stations.

The messages exchanged between the MS and access station are identical for both types of scanning procedures and this overhead ($ULOH_{MS\text{-}AS}$) is calculated according to following expression (1):

$$ULOH_{MS-AS} = 40 + 51 * N\_RcS \qquad (1)$$

The values 40 bits and 51 bits are based on the structure of MOB_SNC-REQ [1].

1) Original procedure according to 802.16j proposal

The procedure proposed in [6] bring a linear increase of uplink overhead between the access station and recommended stations ($UL\_OH_{AS\text{-}RcS}$) in dependence on length of MAC message (UL_Mess), number of hops between the access station and recommended station ($N\_Hops_{AS\text{-}RcS}$) and the amount of recommended stations (N_RcS). The message UL_Mess has a constant length of 155 bits [1]. The overhead can be calculated as:

$$ULOH_{AS-RcS} = UL\_Mess * N\_Hops_{AS-RcS} * N\_RcS \qquad (2)$$

The total uplink overhead is given as a sum of uplink overhead between the MS and access station and the uplink overhead among the access station and recommended stations.

$$ULOH_{original\_802.16j} = ULOH_{MS-AS} + ULOH_{AS-RcS} \qquad (3)$$

2) Proposed procedure

The overhead load in newly proposed procedure is also linearly dependent. The total MAC management messages overhead is can be divided into three parts: i) overhead between the MS and access station ($ULOH_{MS\text{-}AS}$), ii) overhead between the access station and serving BS ($ULOH_{AS\text{-}BS}$) and iii) overhead among the serving BS and recommended stations ($ULOH_{BS\text{-}RcS}$). Thus, the total overhead can be calculated as:

$$\begin{aligned} ULOH_{Optimized} = {} & ULOH_{MS-AS} + ULOH_{AS-BS} \\ & + ULOH_{BS-RcS} \end{aligned} \qquad (4)$$

The overhead between the MS and access station is given by expression (1).

The overhead transmitted from the access station to the serving BS is given by following expression:

$$\mathrm{ULOH}_{AS-BS} = \mathrm{UL\_MessOtp} * \mathrm{N\_Hops}_{AS-BS} * \mathrm{N\_RcS} \quad (5)$$

The ULOHAS-BS depends on the length of message and number of hops between the access station and BS.

Form the Table III, it can observed that the length of MAC message is not fixed. The message contains IDs of all recommended stations (48 bits) and type of scanning for each recommended station (3 bits). Therefore, the message length can be defined as:

$$\mathrm{UL\_Mess}_{Opt\_AS-BS} = 112 + \mathrm{N\_RcS} * 51 \quad (6)$$

The last part of uplink overhead is due to transmission of MAC message from the serving BS to the recommended stations. This part of overhead depends upon: i) length of messages ($\mathrm{UL\_Mess}_{\mathrm{Opt\_BS\text{-}RcS}}$), ii) number of hops between the serving BS and recommended station ($\mathrm{N\_Hops}_{\mathrm{BS\text{-}RcS}}$) and iii) number of recommended stations. The length of all messages is still the same and equals to 163 bits (see Table III, N_RcS=1). The overhead due to transmission between the serving BS and recommended stations is given by following expression:

$$\mathrm{ULOH}_{BS-RcS} = \mathrm{UL\_Mess}_{Opt\_BS-RcS} * \mathrm{N\_Hops}_{BS-RcS} * \mathrm{N\_RcS} \quad (7)$$

B. *Downlink overhead*

The responses sent by recommended stations have similar structures in both cases of scanning procedures. The downlink overhead (DLOH) is created by messages that are transmitted from all recommended stations to the MS. It is composed of two parts:

$$\mathrm{DLOH} = \mathrm{DLOH}_{RcS-AS} + \mathrm{DLOH}_{AS-MS} \quad (8)$$

The first part of the expression ($\mathrm{DLOH}_{\mathrm{RcS\text{-}AS}}$) represents the overhead due to transmission among recommended stations and access station:

$$\mathrm{DLOH}_{RcS-AS} = \mathrm{DL\_Mess}_{RcS-AS} * \mathrm{N\_Hops}_{RcS-AS} * \mathrm{N\_RcS} \quad (9)$$

where $\mathrm{DL\_Mess}_{\mathrm{RcS\text{-}AS}}$ is length of message, $\mathrm{N\_Hops}_{\mathrm{RcS\text{-}AS}}$ is number of hops and N_RcS is number of stations recommended for scanning.

The second part of DLOH overhead ($\mathrm{DLOH}_{\mathrm{AS\text{-}MS}}$) is produced by transmission between access stations and MS (10) and can be found as:

$$\mathrm{DLOH}_{AS-MS} = 48 + 75 * \mathrm{N\_RcS} + \mathrm{TLV\_Length} \quad (10)$$

This part of overhead only depends on the number of recommended stations. The constants correspond to structure of MOB_SCN-RSP message. The amount of parameters coded in TLV (Time/Length/Value) varies, but the length of TLV is same in both algorithms and it is in the order of bytes and therefore it can be neglected.

The padding that is included in the MAC messages to align the message length to bytes (length of padding is several bits) is also left out. The length depends on messages and the impact is insignificant.

IV. RESULTS

From figure 4 can be observed that the overhead linearly increases as the number of recommended stations for scanning increase. The figure shows the total management overhead (sum of uplink and downlink) generated by one MS in one scanning procedure. There are considered different number of hops between the MS and serving BS ($\mathrm{N\_Hops}_{\mathrm{MS\text{-}BS}}$) and different number of hops between the serving BS and recommended stations ($\mathrm{N\_Hops}_{\mathrm{BS\text{-}RcS}}$). The number of hops represents an average amount of hops in the network. For example, if an average distance between the serving BS and recommended station is 2 hops and number of recommended stations is 10, there can be 5 recommended stations 1-hop far from the BS and the remaining 5 stations are 3-hop far from the BS.

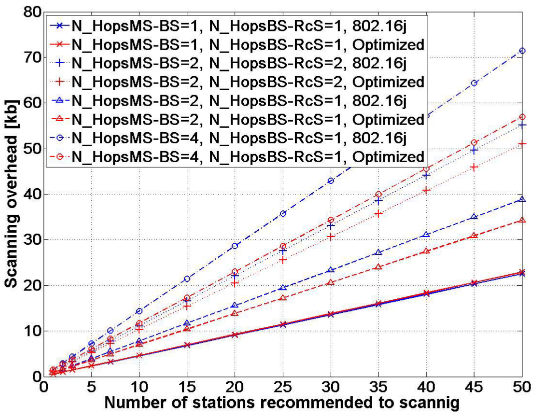

Figure 4. Overhead increase in the dependence on the amount of station that are recommended to scanning

The comparison of both scanning procedures from the point of view of overhead saving is shown in Figure 5. The newly proposed method reduces overhead for all scenarios with more then 1 hop between the MS and serving BS. The decrease of overhead strongly depends on the number of recommended stations and on distribution of number of hops in the section MS–BS and section BS–recommended station. The number of recommended stations affects the decrease of overhead up to approximately 7 stations. Beyond 7 stations, the saving of optimized method becomes nearly constant.

By taking into account the distribution of hops, we can observe that the impact of optimized method increases with the number of hops between the MS and serving BS (compare solid line with cross mark, dashed line with triangle mark and dash-dot line with circle mark in Figure 5.). The saving is more significant for higher number of hops between MS and recommended stations for the same amount of hops between MS – BS and between BS – recommended stations (compare solid line with cross mark and dotted line with plus mark in Figure 5.). The saving effect of optimized procedure is negative in case of 1 hop between the MS and access station, i.e. the serving BS is the access station at the same time. This effect is negatively increasing as the number of hops increases

However, the 1 hop scenario introduces very small overhead (only 8 bits / hop / recommended station) with comparisons to the 802.16j proposal.

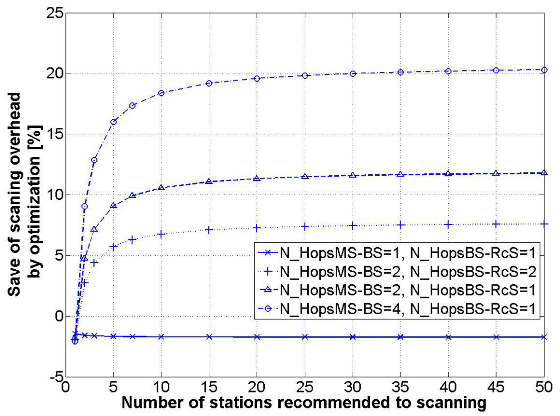

Figure 5. Comparison of overhead reduces by optimized procedure in comparison with original scanning procedure (according to [6]).

V. CONCLUSIONS

This paper proposed optimization of MS neighborhood scanning procedure in WiMAX networks with relay stations The scanning optimization is done from the management overhead point of view.

The modification of scanning procedure is based on saving overhead in the uplink direction by adding identification addresses of all stations recommended for scanning into one scanning request message. The proposition neither modifies messages nor the exchange of messages between MS and access station. This part of procedure corresponds to the IEEE 802.16e standard.

Simulation results show that the proposed modification saves up to 20% compare to the 802.16j proposal. The overhead saving depends on number of hops between the MS and recommended stations, distribution of hops and number of stations recommended to scan.

The future work will focus on optimization of the other phases of handover and further, on minimization of delay caused by handover procedure.

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