Reduction of Relay Overhead in IEEE 802.16j Mobile Multi-hop Relay (MMR) Networks

Kyungmin Lee
Department of Electronic Engineering
Sogang University
Seoul, South Korea
killoop21@sogang.ac.kr

Juwook Jang
Department of Electronic Engineering
Sogang University
Seoul, South Korea
jjang@sogang.ac.kr

Abstract— **In IEEE 802.16j standard, relays are added to increase coverage and improve throughput. However, some overhead results from the inclusion of the relays. One typical example is an addition of R-MAP (Relay MAP) to be included in the header of the frames transmitted from BS (Base Station) to RS (Relay Stations) in non-transparent mode [1]. The R-MAP conveys transmission schedules for the burst data from BS to an RS. Since R-MAP is mostly modulated by the lower MCS (Modulation and Coding Scheme) level (QPSK 1/2 for example), the bandwidth consumption is considerable. Compared with higher MCS level (64QAM 3/4 for example) used by data bursts, it uses 5 times the bandwidth. In this paper, we propose a scheme to compress the R-MAP and show its efficiency through simulation. We also show how to reduce the CID (Connection identifiers) information in MAC headers to further reduce the overhead from relaying. Compression of R-MAP will greatly reduce the overhead from relaying. In other words, we reduce the overhead from relaying in control plane (R-MAP) as well as in data plane (MAC header). As confirmed by the performance evaluation, *MAC Efficiency* of the proposed schemes is higher than that of the Standard schemes by approximately 11%.**

Keywords-IEEE 802.16j, MMR, overhead reduction, R-MAP, MAC header compression, relay

I. INTRODUCTION

The coverage area of IEEE 802.16/16e Standard is often limited, due to significant loss of signal strength. In order to alleviate this problem, a relay-based approach is being pursued by task group 802.16j. The deployment of RS between BS and MS (Mobile Station) cause additional relay overhead. The relay overhead can be analyzed in two points of view, mainly that of Control Plane and that of Data Plane, as follows:

Control Plane

The R-FCH (Relay Frame Control Header) and R-MAP are considered as relay overhead in the Control Plane. In the Control Plane, relay overhead is mainly caused by R-MAP which conveys transmission schedules for the burst data from BS to RS. The bulk of the R-MAP consists of CID which uniquely identifies a connection from BS via RS to MS. As the number of connections increases, the relay overhead may greatly increase since the R-MAP is coded with lower MCS level.

Data Plane

The MPDU (MAC Protocol Data Unit) in a burst is allocated in Data Plane. It consists of MAC header and MSDU (MAC service data unit). MAC header (6 bytes) consists of header type, the length of MPDU, CID (2 bytes) and HCS (Header Check Sum). CIDs take considerable amount of bandwidth here.

All the ensuing discussions apply for communications occurring on relay links only, unless otherwise noted. The rest of the paper is organized as follows. The proposed schemes for reducing R-MAP and compressing MAC header are elaborated in Section II. The performance evaluation results are presented in Section III, followed by the conclusion and future work in Section IV, which completes the paper.

Syntax
DL_MAP_IE() {
DIUC
if (DIUC==14) {
...
} else {
if (INC_CID==1){
N_CID
for (n=0; n<N_CID; n++) {
CID_flag_bit
if (CID_flag_bit==1) {
CID
}
}
OFDMA symbol offset
...

(a) Proposed DL MAP_IE format

Syntax
UL_MAP_IE() {
CID_flag_bit
if (CID_flag_bit==1) {
CID
}
UIUC
if (DIUC==11) {
...
} else {
Duration
Repetition coding indication
if (AAS or AMC UL Zone) {
Slot offset
}
}
}

(b) Proposed UL MAP_IE format

Fig 1. Proposed DL / UL MAP_IE format in R-MAP

II. PROPOSED METHOD

We show how to reduce the R-MAP size in Control Plane and compress the header of MPDU in Data Plane for the reduction of relay overhead. For our scheme, we add a CID Table which includes CID values of all MPDUs in each frame. The CID Table can be set as in the established procedure of the service-specific convergence sublayer (CS). The CS provides any transformation or mapping of external network data into MSDUs. This includes classifying external network SDUs and associating them to the proper SFID (MAC service flow identifier) and CID [1]. In this procedure, BS or RS can generate the CID Table which is ordered as the MPDUs allocated in the frame. Each station retains the CID Table for one frame duration.

A. Reducing R-MAP – Scheme I.

Each station records all CID values of MPDUs in order of presence into the CID Table for each frame. As illustrated in Fig. 1, our R-MAP reduction scheme adds the *CID_flag_bit* in the DL / UL MAP_IE (MAP Information Element). The *CID_flag_bit* in the MAP_IE is the indicator of the changed CIDs. The number of *CID_flag_bits* is equal to the number of CIDs. If the *CID_flag_bit* sets to 1, it indicates the corresponding CID value is changed in the R-MAP. If it sets to 0, the CID value is not changed. The conventional R-MAP includes the CID values of all MPDUs. However, the proposed R-MAP includes only the changed CIDs whose corresponding *CID_flag_bit* is set to 1. The RS updates the CID table through new CIDs indicated by the *CID_flag_bits*. The proposed scheme greatly reduces R-MAP by eliminating redundant transmission of unchanged CIDs.

B. Compressing MAC Header – Scheme II.

We also propose the scheme of compressing MAC header for reduction of relay overhead in Data Plane. The conventional MAC PDU consists of MAC header (6bytes) and payload containing actual data [2]. We reduce redundant CID fields in MAC header, since the CID Table already includes the same CIDs as the CIDs in MAC headers. RS can reconstruct MPDUs, by receiving MAC headers without CIDs on relay link, and then implements MPDU reconstruction using the CIDs from the CID table. However, the MAC headers on access link shall include CID field since MSs cannot decode MAC header without CID field.

III. PERFORMANCE EVALUATION

In order to evaluate the performance of the proposed schemes, the reduction rate of R-MAP and *MAC Efficiency* are defined in Equation (1) and (2) to be used as primary metrics. Key PHY and MAC parameters used in evaluation are summarized in Table I.

The Figure 2 shows the R-MAP size versus the number of CIDs and CID change rate per frame. Since we only pay small additional cost as the *CID_flag_bits* whose size is equal to the number of CIDs, we can save more bandwidth for transmission of R-MAP as less change in the CIDs. For example, the R-MAP size in proposed scheme is smaller than that of standard scheme by approximately 47% when CID Change Rate is 20%.

The MAC header compression can reduce relay overhead as many as 2 bytes per connection in Data Plane. In order to evaluate the performance of Scheme II, we use the *MAC Efficieny* as the ratio between *MAC Data_Rate* and *PHY_Data_Rate* [3]. Here we assume MAC data rate as the useful data transmitted divided by OFDMA frame time length in the DL relayzone. Hence,

$$MAC\_Date\_Rate = \frac{total\_bits \; - \; overhead\_bits}{OFDMA\_frame\_time \;\; (DL\_relayzone)} \quad (1)$$

where *total_bits* denotes the total number of bits transmitted in DL relayzone, and *overhead_bits* does the number of bits that control information including R-FCH, R-MAP, and MAC header. *MAC Efficiency* is given as :

TABLE I : Key PHY and MAC parameter

DL/UL Permutation	FFT size	Channel bandwidth	MCS (DATA)	DL/UL partition
PUSC/PUSC	1024	10 MHz	64QAM 3/4	29 : 18
Sampling factor	Cyclic prefix	Frame duration	MCS (FCH/MAP)	Access/Relay partition
28/25	1/8	5 m/s	QPSK 1/2	1 : 1

$$MAC\ Efficiency = \frac{MAC\_Date\_Rate}{PHY\_Date\_Rate} \times 100\% \quad (2)$$

Fig. 3 shows the simulation result of MAC header compression scheme, under the assumption that the CID changing rate is 50% per each frame. We evaluate the *MAC Data_Rate* only in the DL relay zone. *MAC Efficiency* of the proposed scheme is higher than that of the Standard schemes by approximately 11% in the case that the number of CID is 60.

IV. CONCLUSION AND FUTURE WORK

In this paper, we have proposed two efficiency-improvement schemes, namely reducing R-MAP and compressing MAC header. The proposed R-MAP and Compressing MAC headers reduce relay overhead in Control and Data Plane, respectively. The Performance evaluation shows the *MAC Efficiency* for the proposed scheme is higher than that of the Standard schemes.

REFERENCES

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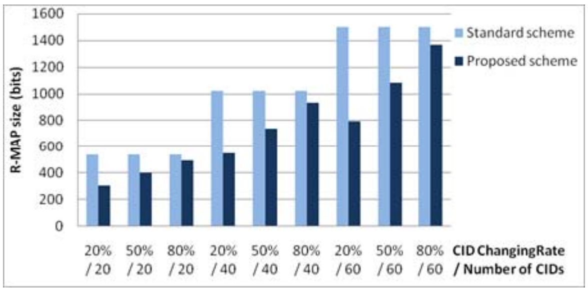

Fig 2. The R-MAP size versus CID changing rate and the number of CIDs

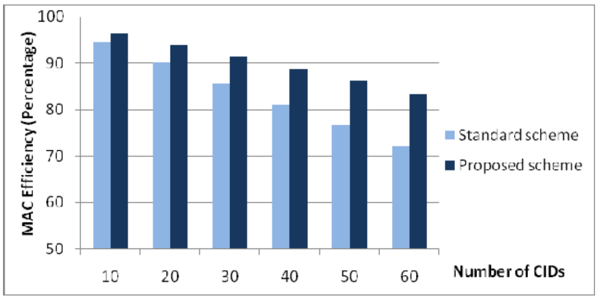

Fig 3. The MAC Efficiency versus the number of CIDs