A Path Selection Scheme Considering Traffic Load for IEEE 802.16j Mobile Multi-hop Relay Networks

Dong Jun Son
Department of Electronic Engineering
Sogang University
Seoul, Korea
sondj@eeca1.sogang.ac.kr

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

***Abstract*—We propose an effective path selection considering current traffic load for IEEE 802.16j MMR networks. Previous schemes either consider channel quality or the number of hops in choosing the effective path for traffic to MSs. Our scheme avoids crowded links even though they have high channel quality. Our scheme balances between the channel quality and the current traffic load, aiming at higher fairness of scheduling for the MSs. The simulation results show our scheme achieves higher throughput as well as fairness among MSs.**

Keywords-IEEE 802.16j, Mobile Multi-hop Relay, path selection, WiMAX, Routing

I. INTRODUCTION

IEEE 802.16j [1], also known as Mobile Multi-hop relay(MMR), requires to obtain the effective path between BS and MS by multi-hop relaying technique with the aid of RSs. Basically, the main function of an RS is to enable data transmissions between RS and MS, between BS and RS, between a pair of RSs to accomplish the communication between BS and MS via the multi-hop relay path as illustrated in Fig. 1. It is possible to transmit data from BS to MS directly or from BS to one of RSs. To maximize data transmission rate, a relay path from BS to MS should be selected efficiently. A straightforward approach to it is using CINR (Carrier to Interference and Noise Ratio) to determine the path selection for wireless networks. However, there are high traffic loads only on some RSs in the MMR network. Such kind of inefficient resource allocation will lead to poor throughput of the network.

In this paper, we devise two metrics, available bit per slot and available slot in 802.16j MMR frame structure. With using these metrics, we actually calculate the data between links and enhance the network fairness. In frame structure as shown in Fig. 1, the available slots appear on both access zone and relay zone, since the frame size is fixed along IEEE 802.16j standards [1].

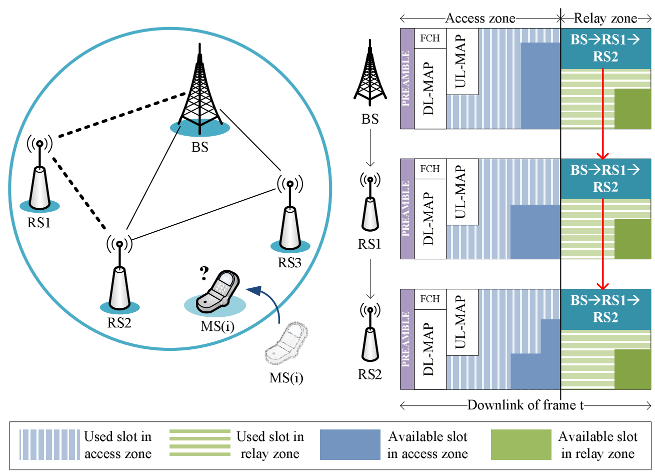

Figure 1. Downlink frame structure in confirming to IEEE 802.16j Draft standard.

We propose an effective path selection and scheduling algorithm to improve the throughput as well as fairness based on IEEE 802.16j MMR networks. The rest of this paper is organized as follows: we will explain related work in Section 2. Section 3, then mentions how to select effective path and Section 3.3 gives an example to show the procedures of relay path selection in the MMR network. Moreover, simulation results and comparisons are given in Section 4. Finally, Section 5 concludes this paper.

II. RELATED WORK

There are two operation modes for the MMR networks. A non-transparent mode transmits DL preamble, FCH (frame control head), DL-MAP, UL-MAP, DCD (downlink channel descriptor) and UCD (uplink channel descriptor) as shown in Fig. 1. In the multi-hop transparent networks, a MS outside of the BS coverage area cannot detect the existence of the BS and gets wireless connection with the

978-1-4244-3709-2/10/$25.00 ©2010 IEEE

BS only when it locates inside the BS coverage area. On the contrary, in the multi-hop non-transparent mode networks, a MS outside the coverage of the BS but inside the coverage area of a RS is able to establish wireless connection with the BS. We considered the multi-hop non-transparent mode for MMR network. First, a previous path selection scheme exploits routing metric ERRI (Effective Radio Resource Index) indicating link channel state [2]. The ERRI can be calculated by inverse number of CINR. Hence, the previous path selection scheme [2] selects path which is the smallest sum of ERRI of each link.

$$\min_k C^k = \sum_{i=1}^{hops} w_i^k \cdot \gamma_i^k \tag{1}$$

where w_i^k be the weight of i-th link, γ_i^k is the ERRI of link i of path k. Based on ERRI and the weight of a link, Equation (1) represents the cost of path, denoted as C^k, in selecting the effective relay path between BS and MS. ERRI path selection scheme, however, is limited by resources allocated to each station. Since the resource is restricted by scheduling, actual available data is close to zero even if the CINR is the best of all paths. Reference [3] used average transmission data per hop as an input metric.

$$P_{r-BS}(n) = \left\{ \frac{L_{r-BS}(n)}{H_{r-BS}(n)} \right\} \tag{2}$$

where $L_{r-BS}(n)$ is the minimum expected link throughput and $H_{r-BS}(n)$ is the hop count of n-th path from RS r to i-th base station BSi. However, hop count does not affect whole network throughput and [3] does not demonstrate in simulation result. Reference [3] is also focused on scenarios which is a new RS enters the network or a mobile RS moves to the network.

III. Proposed Path Selection Algorithm

A. Assumption and metrics

We propose to use a new path selection metric based on the available slot and spectral efficiency. Since the duration of access zones and relay zones is fixed, we have freely available slots in some frames depending on the current load traffic along the paths. The basic idea behind our scheme is to consider these freely available slots as well as spectral efficiency in determining the best path for new traffic. $AS(j,k,t)$ denotes the available slot from station j to k in relay or access zone at frame time t. $SE(j,k,t)$ bits per slot for the link connection station j to k in relay or access zone at frame time t. For example, if CINR for a link is good enough for 64-QAM 3/4 coding rate, then $SE(j,k,t)$ becomes 216 bits per slot as shown in Table 1.

TABLE I. MCS levels and available bit per slot

CINR(dB)	Modulation	Coding rate	Spectral efficiency (bit/slot)
3	BPSK(1bit)	1/2	24
6	QPSK(2bit)	1/2	48
8.5	QPSK(2bit)	3/4	72
11.5	16-QAM(4bit)	1/2	96
15	16-QAM(4bit)	3/4	144
19	64-QAM(6bit)	2/3	192
21	64-QAM(6bit)	3/4	216

B. Path selection and scheduling method

We identify all possible paths leading to MS(i) and transform the wireless network(left side) into a tree(right side) whose leaves are all MS(i) as illustrated in Fig. 2. 16 possible paths are denoted as P(r), r=1,2,…,16. For example, the path P(14) traverses BS, RS3 and RS2 to reach MS(i). We prune the tree by considering some wireless links are too poor to reach 3dB in CINR. We call these links as disconnected links and remove paths which traverse these links. For example, the link between RS1 and RS3 has the CINR below 3dB, both RS1 and RS3 cannot transmit data to each other even with the BPSK 1/2 coding rate which is the worst MCS level.

$$UT(j,k,t) = AS(j,k,t) \times SE(j,k,t) \tag{3}$$

$$T(r,t) = \min_{L(j,k,t)\in P(r)} \{UT(j,k,t)\} \tag{4}$$

$$\underset{P(r)}{MAX} \{T(r,t)\} \tag{5}$$

where $UT(j,k,t)$ is defined as the product of the number of available slots and the spectral efficiency for the wireless link connecting station j and k at frame t as shown in Equation (3). $T(r,t)$ is the achievable throughput for path P(r), at frame t as defined in Equation (4). Equation (5) obtains r whose $T(r,t)$ is the maximum among all possible paths and represents the maximum available throughput to be assigned to MS(i). If $SC(i,t)$ and $D(i,t)$ represent the scheduled throughput and demanded throughput for MS(i) at frame t, respectively, then we have the following relationship as shown in Equation (6).

$$SC(i,t) = \min[D(i,t), MAX_r\{T(r,t)\}] \tag{6}$$

Since SC(i,t) represents the assigned throughput for MS(i) at frame t, we adjust the number of available slots accordingly using Equation (7).

$$AS(j,k,t+1) = AS(j,k,t) - \left\lceil \frac{SC(i,t)}{SE(j,k,t+1)} \right\rceil \tag{7}$$

$$\textit{for all } L(j,k,t) \in P(r')$$

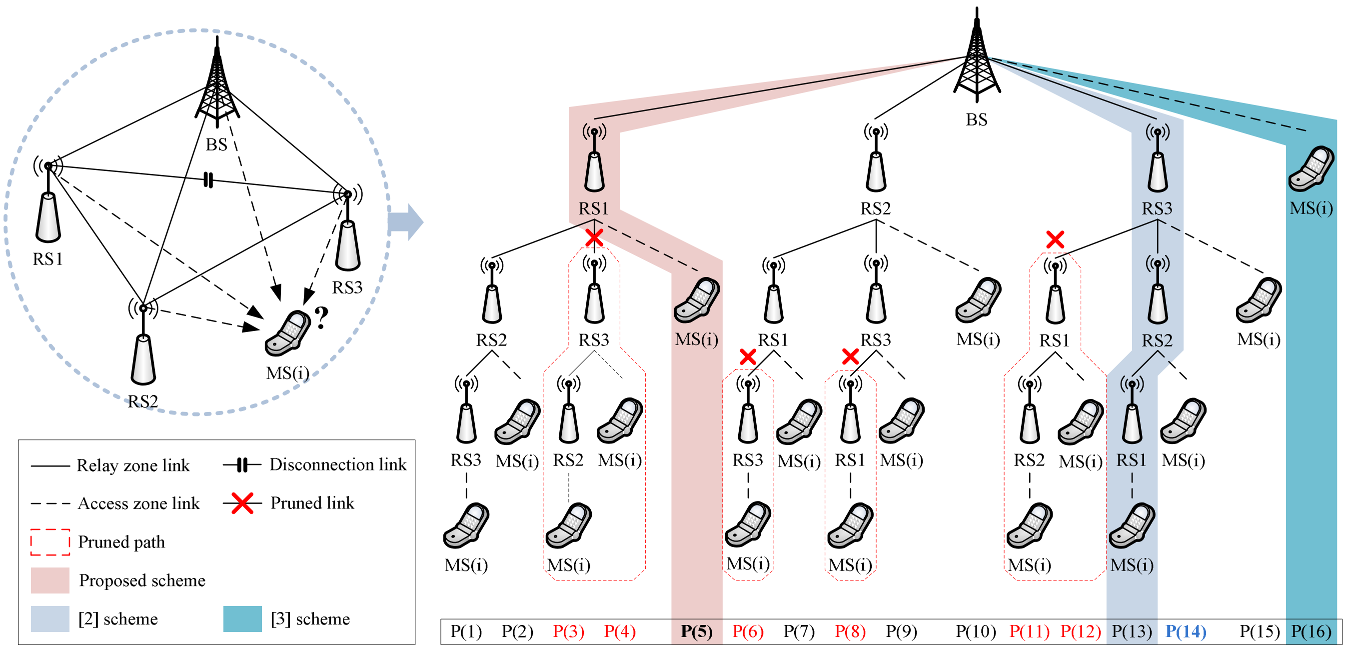

Figure 2. Tree structure of the proposed scheme to compare with previous scheme [2][3] for a 3-RSs topology.

where $P(r')$ is the chosen path for MS(i) and maximizes $T(r,t)$ among all possible P(r)'s. BS allocates resources for all MSs at frame t and then the MS which is not received data is able to be allocated at frame t+1.

C. An example

Fig. 2 shows an example to illustrate the proposed scheme. If we assume the wireless link between RS1 and RS3 is broken (i. e. CINR level is below the minimum threshold for the lowest modulation and coding rate) for the tree in Fig. 2 and prune the tree, then we have the pruned tree. $UT(j,k,t)$ for all possible j, k are listed in Table 2 where M represents MS(i).

Table 3 lists the maximum achievable throughput $T(r,t)$ for all the surviving paths. Our scheme chooses P(5) since $T(5,t)$ gives the maximum value of 5,040 bits per frame. If we use the scheme in [2] which considers only the channel quality (i. e. the sum of spectral efficiency as shown in Equation (1)) the path P(13) would be chosen to transmit 960 bits per frame. The scheme in Reference [3] which considers the hop count would select the path P(16) to transmit 2,160 bits per frame. Refer to Table 3 for comparison of our schemes against [2] and [3]. If we assume that demanded throughput of MS(i), $D(i,t)$, is 800 bits per frame, it is obtained that scheduled throughput $SC(i,t)$ is obtained using Equation (6) as follows.

$$SC(i,t) = \min[800, MAX_{r\in P(i)}\{960,1200,5040,...,2160\}]$$

$$= \min[800,5040] = 800 \qquad (8)$$

After each scheduling, we update the available number of slots, $AS(j,k,t)$, is adjusted to account for the slots used by $SC(i,t)$ as illustrated in Equations (9) and (10). Adjustment is performed on all the links on the chosen path P(5) in Fig. 3.

$$AS(0,1,t+1) = AS(0,1,t) - \left\lceil \frac{SC(i,t)}{SE(0,1,t)} \right\rceil = 50 - \left\lceil \frac{800}{192} \right\rceil = 5 \qquad (9)$$

$$AS(1,i,t+1) = AS(1,i,t) - \left\lceil \frac{SC(i)}{SE(1,i,t)} \right\rceil = 35 - \left\lceil \frac{800}{144} \right\rceil = 6 \qquad (10)$$

TABLE II. EXAMPLE ENVIRONMENT

link L(j,k,t)	Available slot AS(j,k,t)	Spectral efficiency SE(j,k,t)	Utility UT(j,k,t)
L(0,1,t)	50	192 bit	9600 bit
L(0,2,t)	40	144 bit	5760 bit
L(0,3,t)	25	216 bit	5400 bit
L(0,i,t)	30	72 bit	2160 bit
L(1,2,t)	25	192 bit	4800 bit
L(1,3,t)	40	0 bit	0 bit
L(1,M,t)	35	144 bit	5040 bit
L(2,3,t)	40	24 bit	960 bit
L(2,i,t)	25	48 bit	1200 bit
L(3,i,t)	30	72 bit	2160 bit

TABLE III. RESULT OF EXAMPLE

Path P(r)	Proposed scheme T(r,t) (bit)	[2] scheme (sum of SE(j,k,t))	[3] scheme(bit)
P(1)	960	480	528
P(2)	1200	432	400
P(5)	5040 (select)	336	600
P(7)	4800	480	1600
P(9)	960	240	320
P(10)	1200	192	600
P(13)	960	576 (select)	240
P(14)	960	288	320
P(15)	2160	288	1080
P(16)	2160	192	2160 (select)

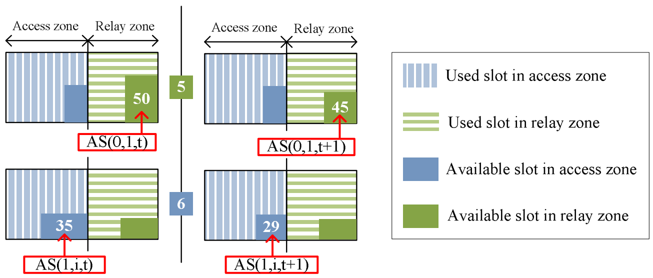

Figure 3. Procedure of example

IV. SIMULATION RESULT

We consider a full buffer traffic model and applied the PUSC subchannelization scheme [1]. A slot consists of two symbols and a sub-channel. According to Table 1, we consider 7 different MCS level. In this paper, spectral efficiency is assigned these MCS level which can be determined by the CINR. We use the Jain's fairness index which is generally accepted [4][5] for measure of fairness. The fairness index gets closer to 1 as the fairness is increased or to 0 as the fairness is decreased [5].

$$f(SC(1,t),SC(2,t),...,(SC(n,t)) = \frac{\left(\sum_{i=1}^{n} SC(i,t)\right)^2}{n\sum_{i=1}^{n} SC(i,t)^2} \qquad (11)$$

Where $SC(i,t)$ is the scheduled data of MS*(i)* and n is the total number of MSs, respectively. In order to evaluate the performance of fairness, Jain's fairness index is suitable for IEEE 802.16j MMR networks [4][5].

We get the Jain's fairness index of proposed scheme to compare with previous schemes along the Equation (11). To improve the fairness the higher Jain's fairness index is required for each MSs. Fig. 4 shows the numerical results of improved average throughput under the number of MSs. More throughputs are increased as the number of MS is increased. With proposed path selection scheme, throughput is more increased as around 23.30% than [2], and 34.56% than [3]. Reference [2] achieves a better performance than our scheme when users are less than around 400. Reference [3] is the worst performance of throughput by considering hop counts. We also compared the performance of Jain's fairness index with [2][3]. The results in Fig. 5 show that the proposed scheme gets the highest value and it is about 0.75. In aspect of fairness, Jain's fairness index of our scheme is more increased as average around twice than [2][3].

V. CONCLUSION

In IEEE 802.16j MMR networks, the path selection scheme between BS and MS has been studied a lot recently [2][3]. However, path selection metric has not been widely addressed and the scheduling method causes the problem of fairness to each traffic load. This paper proposes an effective path selection metric, available data, calculated by spectral efficiency and available slots for IEEE 802.16j MMR networks. The total throughput can be increased by nearly 23~35%, by the proposed scheme, as compared to the conventional path selection schemes. Proposed scheme also shows the effective path selection by Jain's fairness index in aspect of network traffic load.

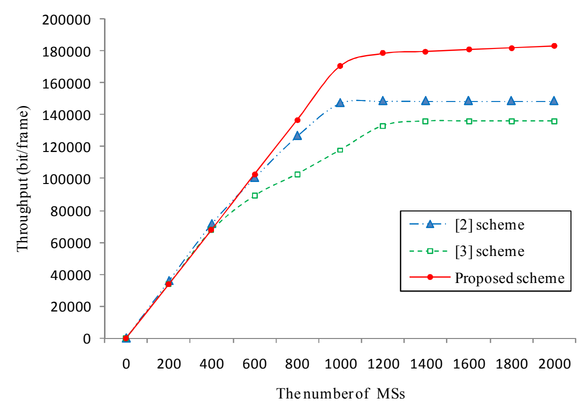

Figure 4. Throughput improvement under the number of MSs.

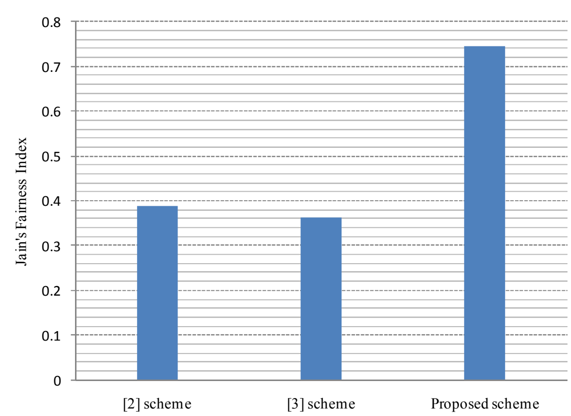

Figure 5. Jain's fairness index

ACKNOWLEDGMENT

This study was supported by the Seoul Research and Business Development Program (10561), Seoul, Korea.

REFERENCE

[1] "Draft Amendment to IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Multihop Relay Specification", IEEE Standard 802.16 Working Group, December 2007.

[2] S.-S. Wang, H.-C. Yin, Y.-H. Tsai, and S.-T. Sheu, "An effective path selection metric for IEEE 802.16-based multi-hop relay networks," Proceedings of the IEEE Symposium on Computers and Communications, Jul. 2007, pp. 1051–1056.

[3] Sojeong Ann, Kyung Geun Lee, and Hyung Seok Kim, "A Path Selection Method in IEEE 802.16j Mobile Multi-hop Relay Networks", The Second International Conference on Sensor Technologies and Applications, 2008, pp.808-812.

[4] Dianati, M. Shen, X and Naik, S, "A new fairness index for radio resource allocation in wireless networks", Wireless Communications and Networking Conference, 2005 IEEE, March. 2005.

[5] Li-Chun Wang and Wei-Jun Lin, "Throughput and fairness enhancementfor OFDMA broadband wireless access systems using the maximum C/I scheduling", Vehicular Technology Conference, 2004 VTC2004-Fall 2004 IEEE 60th. Sept.