Dynamic Frame Scheduling with Load Balancing for IEEE 802.16j

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Abstract— **In this paper, we consider a multi-hop relay networks in IEEE 802.16j system with the full frequency-reuse capability, in which a frame structure can be asymmetrically divided into two different intervals, one for access zone to base station (BS)/relay station (RS)-mobile stations (MSs) communication and the other for relay zone to BS-RS communication, while the same radio resource is fully reused by every RS in the cell. This paper proposes a frame scheduling algorithm that improves the overall system throughput by reducing waste of radio resource through balancing of resource allocation in each relay station (RS). The proposed algorithm is divided into two stages: first, a boundary between access zone and relay zone is scheduled by BS and determined dynamically; second, traffics that will be retransmitted by automatic repeat request (ARQ) and generated by difference between current and scheduled MCS (Modulation and Coding Scheme) level are scheduled by RS. The simulation results show that proposed algorithm improves the overall system throughput approximately by 35% over a conventional frame scheduling algorithm without any load balancing capability.**

Keywords- IEEE802.16j; frame scheduling; WiMAX; load balancing;

I. INTRODUCTION

IEEE 802.16j multi-hop relay draft standard is considered as a useful means of coverage extension and throughput enhancement of the IEEE 802.16e [1]. Multi-hop relay system deploy RSs that cost less than BS to more efficiently serve cell edge and service outage area. With RSs deployed, downlink and uplink sub-frames are asymmetrically divided into two different intervals, one for access zone to BS/RS-MSs communication and the other for relay zone to BS-RS communication. Therefore BS and numerous RS serve each subordinate MSs, in contrast with IEEE 802.16e that only BS is serving station.

However, we should consider two problems that were not revealed in IEEE 802.16e. First, if the boundary between access zone and relay zone is fixed, it is difficult to allocate resource efficiently because access and relay traffics vary at each frame. Second, since radio resources in access zone are fully reused by RS, traffic load can be unbalanced when MS's traffic distribution is non-uniformed. As shown in Figure 1, a serving station(BS or RS) that served low traffics compared to others remains waste zone from the end of the serving time to the end of access zone, As a result, the utilization of radio resource is reduced as much as waste zone.

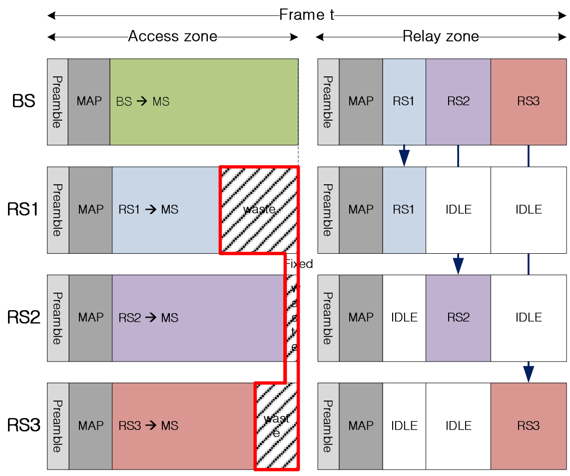

Figure 1. Example of Wasting Resource in IEEE 802.16j System

In this paper, we propose a new frame scheduling algorithm to solve two problems. It is the kernel idea of proposed algorithm that the length of access zone at t+1 frame can be regulated by allocating resources of relay zone at t frame. Therefore, resources can be allocated without any waste zone through traffic load balancing, and the length of access zone can be determined as the new boundary between access zone and relay zone by scheduling result.

The simulation results show that the overall system throughput by the proposed algorithm is increased approximately by 35% over a conventional frame scheduling algorithm with fixed boundary.

The rest of the paper is organized as follows. Section II formally presents out system model and problem formulation. Then, we proposed dynamic frame scheduling algorithm in Section III. Section IV shows the simulation results. Finally, the paper is concluded in Section V.

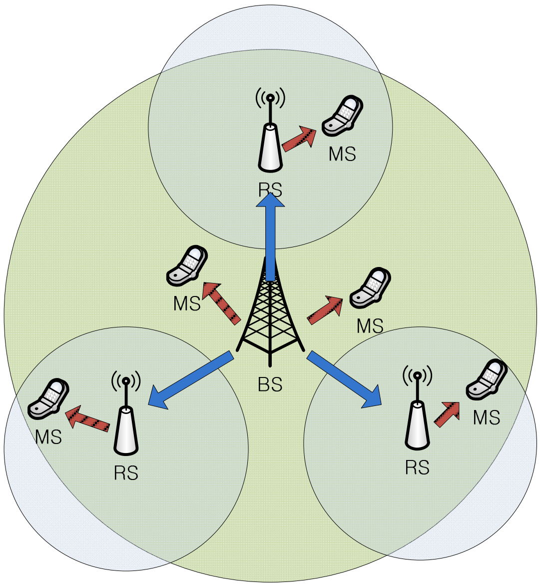

Figure 2. Typical IEEE 802.16j Network Model

II. SYSTEM MODEL AND PROBLEM FORMULATION

A. System Model

A typical IEEE802.16j network model is shown in Figure 2. It consists of one BS and several RSs that are connected to the BS using one or more hops. Even through more than two hops can be exploited via RSs, we consider a simple relay with two hops via a single RS as shown in Figure 2.

Downlink frame structure of IEEE 802.16j is divided into two intervals, which are an access zone and a relay zone. The access zone is an interval that BS and all RSs serve MSs in their service areas, and BS transmits the data to RSs in the relay zone. In downlink relay zone, only BS transmits data, whereas in access zone, not only BS but also all RSs within the cell transmit data simultaneously.

In the system using overlapped resource allocation scheme, in which BS and all RSs reuse the same radio resources for access zone, a non-uniform traffic distribution may cause inefficient resource utilization. Hence we should consider link selection problem that deals with which MS is served by BS or RS. We assume that the access link for each MS is already set up with load-balancing to simplify problem and focus on scheduling algorithm only.

After all MSs set up their access link, a frame scheduler which may be Proportional Fair (*PF*) scheduler generally performs resource allocation through requiring of each MS. In [3], it is proved that *PF* scheduler must maximize the sum total of $\ln u_k$, as follows:

$$PF = \arg\max \sum_{k=1}^{K} \ln u_k \,, \qquad (1)$$

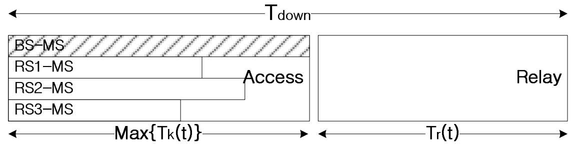

Figure 3. Boundary for Access Zone and Relay Zone in Downlink Frame

where u_k denote user k's instantaneous throughput(R_k) or average throughput(R_k^{avg}). The PF scheme is to assign one user taking turn to transmit at each epoch decision time [4]. The user k^* is selected according to:

$$k^* = \arg\max \frac{R_k}{R_k^{avg}} \,. \qquad (2)$$

B. Problem Formulation

The result of resource allocation by the scheduler can be determined the boundary between access zone and relay zone dynamically. If the boundary between access zone and relay zone is fixed, radio resources can be insufficient or wasted in access zone and relay zone by unbalanced traffic load distribution. Thus we should consider the amount of allocated resource in access zone and relay zone to determine the appropriate boundary.

Figure 3 shows the example of determining the dynamic boundary for downlink. The length of downlink frame is fixed at T_{down}, which is the total length of relay zone and access zone. The length of access zone is determined by the link that has the longest length[5]. Therefore, it can be formulated as follows:

$$\sum_{N=1}^{n} T_r(N,t) + \max_{N\in\{0,\ldots,n\}} \{T_a(N,t)\} \le T_{down} \,, \qquad (3)$$

where $T_r(N,t)$ denotes the length of relay zone of RS_N at t frame, and $T_a(N,t)$ denote the length of access zone of BS(N=0) or RS(N=1,2,…,n) at t frame. In case of Figure 3, the length of BS-MS link is determined as the length of access zone because the length of BS-MS link is the longest.

In order to balance the traffic load in access zone, resources have to be allocated uniformly in relay zone at previous frame. Basically, the traffics that are allocated in relay zone at t frame are served in access zone at t+1 frame, so the traffic quantity in relay zone at t frame is equal to the traffic quantity in access zone at t+1 frame, as follows:

$$\begin{aligned} &R_r(N,t)\times\{T_r(N,t)+T_{reTX}(N,t)\} \\ &= R_a(N,t+1)\times T_a(N,t+1)\,, \end{aligned} \qquad (4)$$

where $R_r(N,t)$ denotes the throughput of BS-RS_N link at t frame and $\overline{R_a(N,t+1)}$ denotes the average throughput of RS_N-MS link at t+1 frame. $T_{reTX}(N,t)$ is the length that can be generated by means of retransmitted traffics. In 802.16j system, packet error can be often generated by transmitting with very high bit-rate, so we should consider $T_{reTX}(N,t)$ to calculate accurate length. The formula (4) can be transformed as follows:

$$T_a(N,t+1) = \frac{R_r(N,t)\times\{T_r(N,t)+T_{reTX}(N,t)\}}{\overline{R_a(N,t+1)}}, \qquad (5)$$

Through the formula (5), the length of access zone at t+1 frame can be calculated since all of parameters on the right side of equation are already known. In other words, the length of access zone at t+1 frame is determined by the scheduling result in relay zone at t frame and the traffic that will be retransmitted.

The MCS level for channel state of RS-MS link is updated by each period, so the difference of MCS level between scheduling process and service process can be caused. Therefore the traffics that aren't transmitted at previous frame can remain in the buffer of RS, so we should also consider these traffics to calculate accurate length, as follows:

$$T_a(N,t+1) = \frac{R_r(N,t)\times\{T_r(N,t)+T_{reTX}(N,t)\}}{\overline{R_a(N,t+1)}} + T_{Buff}(N,t+1), \qquad (6)$$

where $T_{Buff}(N,t+1)$ denotes the length that can be generated by the traffics in the buffer of RS at t+1 frame.

The proposed scheduling algorithm, is referred to *LB*, is maximizing the sum of each length of access zone at t+1 frame, which is given by the logarithm. Then we can maximize the load balancing, as follows:

$$LB = \max\{\sum_{n=1}^{N}\log(T_a(N,t+1))\}. \qquad (7)$$

III. PROPOSED SCHEDULING ALGORITHM

The proposed algorithm is divided into two stages. First, a boundary between access zone and relay zone is scheduled by BS. Second, traffics that will be retransmitted by ARQ and will be generated by difference between current and scheduled MCS level are scheduled by RS.

A. *Scheduling in BS*

The flowchart in Figure 4 shows the scheduling process in BS. The purpose of scheduling in BS is determining boundary between access zone and relay zone with load balancing in access zone.

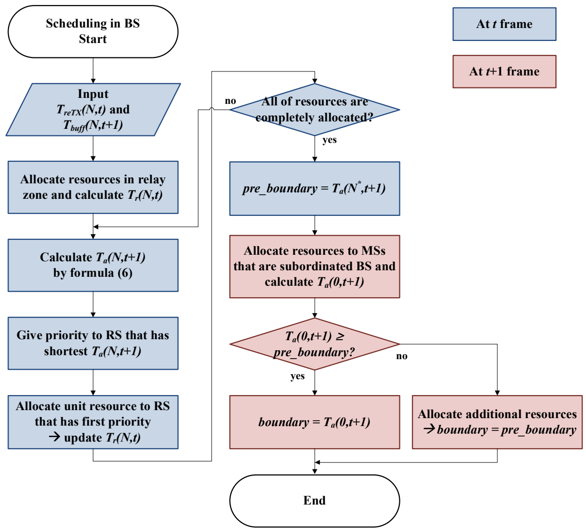

Figure 4. The Scheduling Process in BS

First, BS collects the traffic information that will be generated by retransmission and difference between current and scheduled MCS level at previous frame. Then, BS allocates radio resources to MSs that satisfy the minimum requirement of each MS, and calculates $T_a(N,t+1)$ by formula (6). BS gives priority to RS that has the shortest $T_a(N,t+1)$, and allocates a unit resource to RS that has first priority. The chain of this process is repeated until all of resources are allocated entirely, as a result traffic load balancing among RSs is guaranteed. RS_{N^*} denotes the N^*th RS which has the longest length of access zone among RSs. $T_a(N^*,t+1)$ is determined as *pre_boundary*, and scheduling process at *t* frame is completed.

BS allocates resources to subordinate MSs that satisfy the minimum requirement of each MS at *t*+1 frame, and calculates $T_a(0,t+1)$. If $T_a(0,t+1)$ is longer than *pre_boundary*, the final boundary is determined as $T_a(0,t+1)$. On the other hand, if $T_a(0,t+1)$ is shorter than *pre_boundary*, BS allocates resources additionally until $T_a(0,t+1)$ is set to *pre_boundary*, and the final boundary is determined as *pre_boundary*. Then, scheduling process in BS is completed.

B. *Scheduling in RS*

The flowchart in Figure 5 shows the scheduling process in RS. The purpose of scheduling in RS is considering traffics that will be retransmitted by ARQ and will be generated by difference between current and scheduled MCS level.

Each RS receives traffics that will be served to subordinate MSs at next frame from BS, and then considers two things before transmitting to subordinate MSs, as follows. First, if the traffics that have to be retransmitted from BS are existed, RS saves this information that will be requested to retransmit to BS at uplink frame. Second, RS considers the difference between current and scheduled MCS level for RS-MS link. If

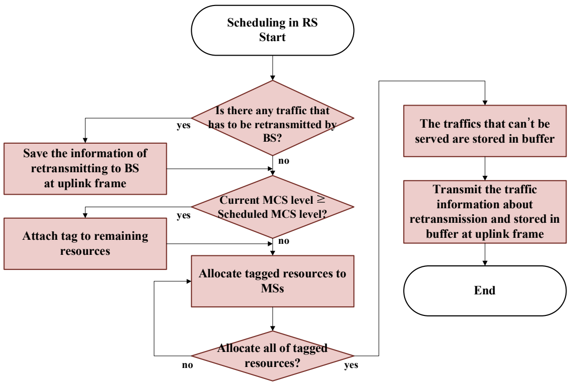

Figure 5. The Scheduling Process in RS

the current MCS level is higher than the scheduled MCS level, since RS can transmits traffics to subordinate MS with higher MCS level, radio resources remain as much as the difference between current and scheduled MCS level. These radio resources are managed by attached tag. On the other hand, if the scheduled MCS level is higher than current MCS level, RS should transmit traffics to subordinate MSs with lower MCS level. However, radio resources are not enough to manage traffics which will be served to MSs. In this case, RS allocates additional tagged resources to MSs as much as each MS needs. If RS can't serve some traffic to MS after allocating all tagged resources, these traffics are stored in buffer of RS to serve at next frame and RS saves this information to inform BS at uplink frame. Then, scheduling process in RS is completed.

As seen above, the proposed scheduling algorithm can guarantee traffic load balancing of each RS-MS link and can dynamically determine the boundary between access zone and relay zone.

IV. Simulation Results

The simulation scenario is performed as follows. The cell radius is 1 km, and BS is located in the center of the cell. We deploy 3 RSs, in which are located around BS at a 2/3 position between BS and cell boundary. All RSs can receive signal with the highest MCS level (64QAM 5/6) from BS. 250 MSs are uniformly distributed throughout the cell. More detailed parameters are shown in Table 1. Table 2 is the MCS table used in simulation, which shows CINR levels required for the given modulation and coding set (MCS) subject to the given channel model.

Figure 7 shows the performance of system throughput with respect to various numbers of users. As can be seen from the figure, the system throughput performance is improved with proposed algorithm approximately by up to 35% over a conventional algorithm which is PF scheduling algorithm with fixed boundary. It is obvious that the performance gain is obtained by ensuring the efficiency by reducing the resource waste with the dynamic boundary for loading balancing, which deals with any resource waste for the access link of each RS. This performance gain becomes clearer from Figure 8, which shows the resource efficiency of each access link associated with a node for the different scheduling algorithms.

Table 1. Simulation Parameters

Parameter	Value
Carrier Frequency	2.3GHz
System Bandwidth	10 MHz
Transmit Power	BS : 20W, RS : 10W
Frame Duration	5ms
RS Configuration	3 Fixed RS; Each RS located at 720m position from BS
FFT Size	1024
Traffic Model	Full buffer model
Scheduling Algorithm	Proportional Fair and Proposed Algorithm

Table 2. MCS Table for Adaptive Modulation & Coding

MCS level	Coding rate	Required CINR (dB)
QPSK	1/12	-3.95
	1/6	-1.65
	1/3	1.5
	1/2	4.3
	2/3	7.95
16QAM	1/2	9.3
	2/3	13.1
	3/4	15.8
64QAM	2/3	18.45
	5/6	24.8

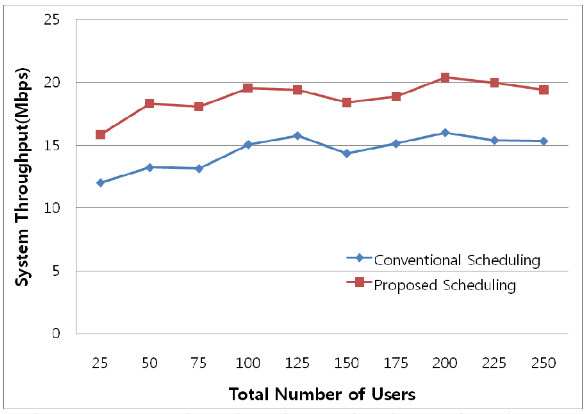

Figure 7. System Throughput for Varying the Number of Users

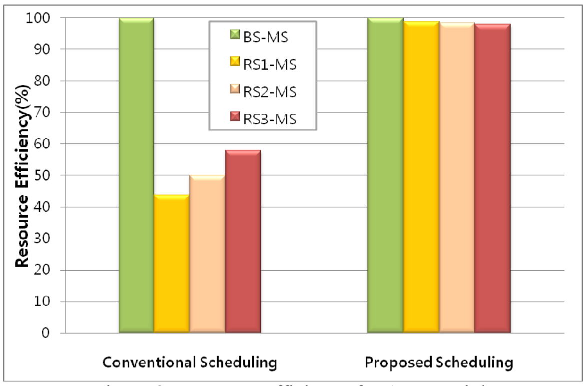

Figure 8. Resource Efficiency for Access Link

V. CONCLUSION

In multi-hop relay networks in IEEE 802.16j system with the full frequency-reuse capability, if the boundary between relay zone and access zone is fixed, the system throughput performance can be reduced by wasting radio resources. Hence we proposed a new frame scheduling algorithm with dynamic boundary, and evaluated performance. We formulated the fact that resource allocation in relay zone at t frame determines the length of access zone at t+1 frame, and this formula is used as scheduling metric. The simulation result shows that proposed algorithm improves the overall system throughput approximately by 35% over a conventional scheduling algorithm with fixed boundary. Also, the proposed algorithm considers the traffics that will be retransmitted by ARQ and generated by difference between current and scheduled MCS level. Therefore, we provide an accurate framework to implement the system.

ACKNOWLEDGMENT

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