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Combined centralised and distributed mechanism for utilisation of node association in broadband wireless network

A Ulvan[*1]**, M Ulvan**[1]**, H Pranoto**[2]

[1]Department of Electrical Engineering, The University of Lampung Jl. Prof. S. Brodjonegoro No.1 Bandar Lampung 35145, Indonesia
[2]Department of Electrical Engineering, Medan State Polytechnique Jl. Almamater No.1 Kampus USU Medan 20155, Indonesia

[*]E-mail: ardian.ulvan@eng.unila.ac.id

Abstract. Mobile broadband wireless access system has the stations that might be fixed, nomadic or mobile. Regarding the mobility, the node association procedure is critical for network entry as well as network re-entry during handover. The flexibility and utilisation of MAC protocols scheduling have an important role. The standard provides the Partition Scheme as the scheduling mechanism which separates the allocation of minislots for scheduling. However, minislots cannot be flexibly reserved for centralised and distributed scheduling. In this paper we analysed the scheduling mechanism to improve the utilisation of minislots allocation during the exchange of MAC massages. The centralised and distributed scheduling is implemented in some topology scenarios. The result shows the proposed mechanism has better performance for node association than partition scheme.

1. Introduction

The MAC header of IEEE802.16 broadband wireless system is divided into two parts which are Generic MAC (GM) and Bandwidth Request (BR) [1]. GM is dealing with transfer data or MAC massages. In addition, BR has responsibility on sending bandwidth request packets to a base station (BS). In the legacy single connection of mobile station (MS) to BS, the connection management including node association and network entry seems have no critical issue. However, on the contrary, there are some issues when the extended connection and network such as relay network, multiple and mesh connection is present. What would happen when a BS is connected to multiple MSs? How can it manage the connection? These are some common issues that have to be answered and solved

In IEEE 802.16e standard, a MS are allowed to send data only at scheduled time which is decided by BS. The BS communicates to all MSs in the beginning of each frame in uplink map (UL-MAP). As we can found from the standard, the number of bandwidth allocation procedures and QoS are provided. However, particular scheduling method and reservation technique have not been standardised yet.

In Time Division Multiple Access (TDMA) mode, the data transfer has been scheduled by time. The time is divided between frames separated by guard time. Each frame is further divided between uplink (UL) sub-frame and downlink (DL) sub-frame. The UL sub-frame once again divided between three periods namely ranging period, bandwidth contention period and data uplink period. UL-MAP contains duration of these periods including time slots for each MS to send data to BS in uplink sub-frame. In uplink direction, MSs sent data to BS in corresponding allotted slots. Any MS is not allowed to use any other MS's uplink slots for data transfer. Therefore, to accomplish MS requirements the slots allocation is needed.

2. MAC scheduling and QoS Issues

In order to have a better support for QoS requirement the standard defines key parameters like delay, minimum reserved bandwidth, bandwidth request mechanism and flow type association. However, it is

still not clear how the parameters would be employ, also when and where they should be used to obtain maximum QoS. It can be assumed that the implementation of an appropriate scheduling algorithm is the best way to support maximum application in parallel on this system.

Scheduling has to be done in both directions uplink and downlink. Downlink scheduling seems relatively easy because BS has all packets and their status. In contrast, the uplink scheduling seems more complex since it has various parameters such as numbers of client (MSs or RSs), delay bounds, associated flows and bandwidth requirements of each flow. In spite of different constraints between downlink and uplink direction, the different scheduling algorithm may or may not be implemented in both direction [1].

Additionally, it is necessary to investigate if the system require two scheduling components (at BS and at MS), or only single component of scheduling sitting at the BS can properly schedule all traffic. The IEEE 802.16 standard supports four different flow classes for QoS and the MAC supports a request-grant mechanism for data transmission in uplink direction. These flows are associated with packets at MAC level. Each connection has a unique flow type associated with it. The IEEE 802.16 standard does not define any slot allocation criterion or scheduling algorithm for any type of service. A scheduling module is necessary to design UL-MAP to provide QoS for each SS. Slots assignment for connections is done by BS and included the same in UL-MAP. The IEEE 802.16 standard support many traffic types (data, video, voice) with different QoS requirements. The 802.16 standard defines the following four types of service flow with distinct QoS requirement [1]:

- Unsolicited Grant Services (UGS)
- Real-Time Polling Services (rtPS)
- Non-Real-Time Polling Services (nrtPS)
- Best Effort (BE) Services

As described on IEEE 802.16e standard, each flow has its distinct QoS parameters. For UGS flow bandwidth request is not needed but for other flows queue length (incremental or aggregate) at MS is included in bandwidth request packet to represent the current demand. Bandwidth is always requested on a per connection basis. The IEEE 802.16e defines the following two ways for allocation of bandwidth grants [1]:

- Grant per Connection (GPC) Bandwidth is allocated to a connection and MS uses this grant only for this connection.
- Grant per Subscriber Station (GPSS) MS granted bandwidth aggregated into a single grant. This MS needs more intelligent to distribute this grant into various flows, running at this MS.

3. Scheduling Mechanism

This section point up the partition scheme mechanism which is described on the IEEE 802.16 standard, then we illustrate the centralised and distributed mechanisms as well as the node association in a network topology with relay capability.

3.1 Partition Scheme Mechanism

Obviously, in relay system the mesh mode topology is adopted. In IEEE 802.16 standard, the Time Division Multiplexing (TDM) radio access technology between clients (RSs and MSs) and between the clients and the mesh BS is take on. A radio channel is divided into physical slots (PSs) using time sharing, and multiple PSs are grouped as a frame. Figure 1 shows the frame structure.
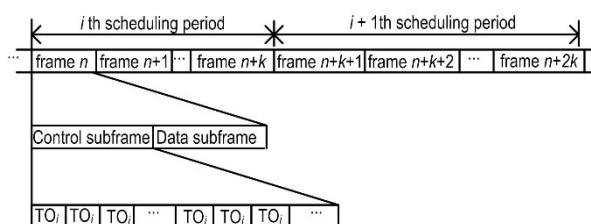

Figure 1. The frame structure of mesh network based on IEEE 802.16e

As described in [2], a frame is allocated for the purposes of control and management (control subframe) and information (data subframe). In the control subframe part, the signalling message is carried by the Transmission Opportunities (TOs). The TO for centralized scheduling is denoted as TOc, additionally the TOd is denoted for distributed scheduling.

The scheduling is to schedule minislots to serve different clients. The numbers of TOcs and TOds in a control subframe are configurable. On the other hand, the data subframe carries the user data and is further divided into 256 minislots. The transmission rate that the minislot can provide is assigned as r bits/sec. According to standard, the rate is not fixed but depends on several factors (e.g., channel coding, modulation, frequency band, etc) [1]. A minislot has a property called "minislot reuse" by which it can be reused by multiple clients as long as the clients are geographically separated or they do not interfere each other. In this paper we assume the multiple clients may be allowed to transmit in the same minislot.

The data traffics in the wireless mesh network can be divided into two categories [3]: intra-network traffic and inter-network traffic. Intra-network traffics are the traffics between two or more clients in the same wireless mesh network (i.e. MS to RS/BS, RS to BS, and vice versa). In addition, internetwork traffics are the traffics between the clients via different BSs, or the traffics from/to backhaul applications. A data subframe can simultaneously carry the intra and inter-network traffic data. The distributed scheduling mechanism is assigned for minislot allocation for the intranetwork traffic and the centralised scheduling mechanism is for the internetwork traffic. It is important to carefully schedule the minislots in a data subframe for both kinds of traffics to optimise minislot utilisation.

IEEE 802.16 recommends to partition a data subframe into two parts for the two schedulings mechanism which is known as the "partition" scheme. However, this may not be the best solution due to the fact that the partitioned boundary may not precisely capture the traffic pattern, and the minislots may not be fully utilized. Figure 2 shows the partition scheme mechanism. The first 128 minislots are assigned for inter-network traffic purposes. The rest 128 minislots are assigned for intra-network traffic.
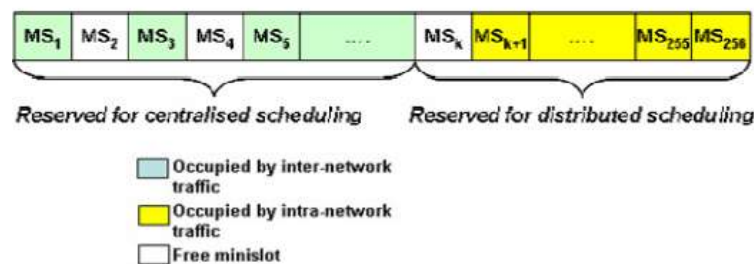
Figure 2. IEEE 802.16 Partition Scheme

3.2 Centralised Mechanism

The centralised scheduling mechanism for the communication between the BS to MSs has been specified on the IEEE 802.16e standard. The scheduling mechanism could also be adopted to make mobile possibility on relay station (mobile relay-MR). The BS acts as a scheduler and determines transmission and reception minislots for each client station (MS/MR). A scheduling tree rooted at the BS is established for the routing path between each client and the BS. A scheduling tree is denoted as follow and depicted on figure 3 below.
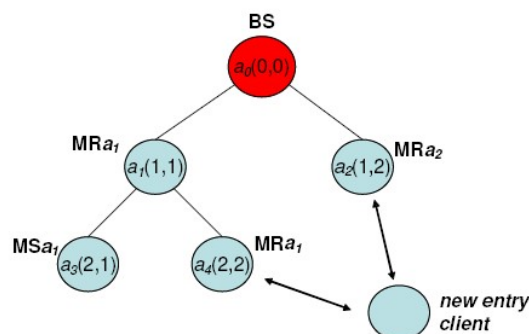
Figure 3. The scheduling tree of node association in centralised scheduling

The tree (T) can be written as follow:

$$T = \{a_0(k_{a_0}, n_{a_0}), a_1(k_{a_1}, n_{a_1}), a_2(k_{a_2}, n_{a_2}), \ldots a_i(k_{a_i}, n_{a_i}), \ldots\} \tag{1}$$

where k_{a_i} is the layer number, n_{a_i} is the position number in layer k_{a_i}, and (k_{a_i}, n_{a_i}) is the index number of the node. The index number of BS is (0,0).

Before a client executes the registration procedure to join the network, it selects a network node with smallest layer number from all neighbouring network nodes as the candidate node. Then the client sends the registration message (network entry procedure) to the mesh BS through the candidate node. Upon receipt of the registration message, the BS sets the new entry client as the child of the candidate node in the scheduling tree, updates the scheduling tree, and then broadcasts the scheduling tree to all Stations. By completing the procedure, the new entry client obtains a node ID.

The centralised scheduling consists of two stages. In the first stage, the BS collects bandwidth requests from all client stations. In the second stage, the BS calculates and then distributes the transmission and reception schedule to all Stations. The time period for exercising the two stages is called as *scheduling period*. The schedule assigned in the ith scheduling period is referenced in the $i + 1$st scheduling period as shown in Figure. 1. Take Figure. 2 as an example, where MR_{a_i} ($i = 1$, 2, 3, 4) requests transmission rates, R_{u,a_i} and R_{d,a_i} for data transmission to and data receipt from the BS respectively. The MR_{a_i} first checks whether the number n_{f,a_i} of free minislots is smaller than $\left\lceil \dfrac{R_{u,a_i}}{r} \right\rceil + \left\lceil \dfrac{R_{d,a_i}}{r} \right\rceil$. If so, MR_{a_i} quits the centralised scheduling. Otherwise, the centralised scheduling exercises as follows: Based on the scheduling tree, the client station with larger k_{a_i} and smaller n_{a_i} transmits the UL signalling messages first, while the client station with smaller k_{a_i} and smaller n_{a_i} relays the DL signalling message first.
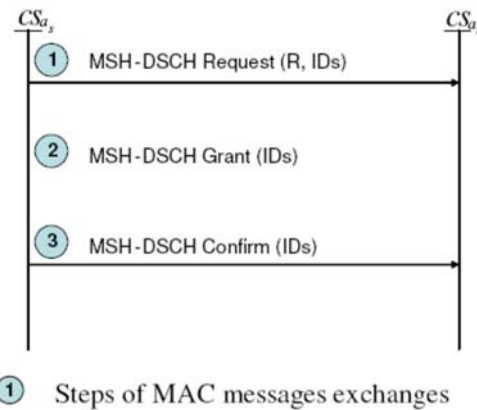
3.3 Distributed Mechanism

Additionally, the distributed scheduling will be assigned when client station CS_{a_s} has data to be transmitted with transmission rate R to its neighbour CS_{a_r}. The CS_{a_s} first checks whether n_{f,a_s}, is smaller than $\left\lceil \dfrac{R}{r} \right\rceil$. If so, CS_{a_s} quits the distributing scheduling. Otherwise, the scheduling is performed to reserve minislots for data transmission as shown in Figure. 6. Then, after the execution of distributed scheduling, CS_{a_s} can transmit data to CS_{a_r} in the reserved minislot without collision [4].

4. Flexibility and Utilised MAC Message

According to the scheme that have been described on previous section, the MAC massages flows for centralised and distributed scheduling mechanism can be seen on Figure. 4 and Figure. 5 respectively. The combination of centralised and distributed mechanism for node association MAC scheduling also have the positive effects since the minislot allocation can be more flexible, and the minislot utilisation is increased, shown in figure 6.
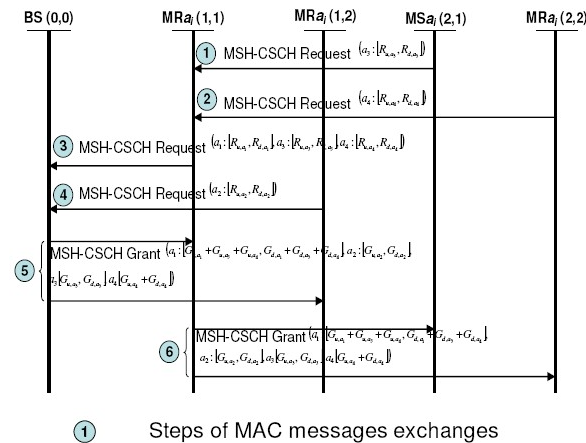
Figure 4. MAC massages exchanges for centralised scheduling

Figure 5. MAC massages exchanges for distributed scheduling
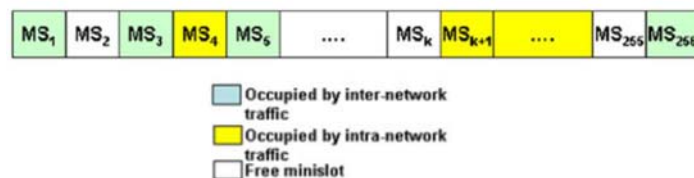
Figure 6. Flexible and utilised minislots by combine centralised and distributed mechanism.

5. Conclusion

The IEEE 802.16e standard has provided the partition scheme mechanism by dividing fixedly the 256 minislots for centralised and distributed scheduling. However, the partitioned boundary may not precisely capture the traffic pattern since the relay stations with multiple connections in mesh topology is obtainable, therefore the minislots may not be fully utilised. The use of combine centralised and distributed mechanism is more flexible and effective in utilisation of minislots.

Acknowledgment

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