Centralized Scheduling Solution for the IEEE 802.16 Mesh Mode Based on Novel Base Station Scheduling Algorithm

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Abstract
In IEEE 802.16 Mesh a node that has a direct connection to backhaul services outside the Mesh network is termed a Mesh Base Station (MBS). All other nodes of a Mesh network are termed Mesh Subscriber Stations (MSS). The MAC scheme used is TDMA and the resource allocation is in terms of time slots within a frame. The standard neither specifies an algorithm for scheduling of the slots to different MSSs; nor specifies any routing algorithm. Scheduling and routing will have a significant impact on the performance of the system and will largely decide the end to end QoS to different users. In this paper, centralized scheduling algorithms are developed, which are a QoS mechanism and a BS Scheduler for the IEEE 802.16 Mesh mode to ensure meeting the QoS requirements, and a Novel BS Scheduling (NBSS) algorithm for IEEE 802.16 mesh mode.
Keywords: CENTRALIZED SCHEDULING SOLUTION, IEEE 802.16, MESH MODE, NOVEL BASE STATION SCHEDULING ALGORITHM

1. Introduction

It is now possible to gain access to data services anywhere, anytime via Wireless Local Area Networks (WLANs) and extended Public Wireless Metropolitan Area Networks VVMANs), which are inexpensive means of providing last-mile connectivity to the Internet. There exist many WLANs techniques, such as Wi-Fi, Bluetooth, HiperLAN, HomeRF, and WiMAX. Each technique has its own niche depending on the deployment requirements [1-4].

This research focuses on WiMax (Worldwide Interoperability for Microwave Access) technique that is receiving an overwhelming acceptance by the majority in the communication industry. WiMAX has become synonymous with the IEEE 802.16 Wireless Metropolitan Area Network (MAN) air interface standard. In its original release, the 802.16 standard addressed applications in licensed bands in the 10 to 66 GHz frequency range. Subsequent amendments have extended the IEEE 802.16 air interface standard to cover on-line of sight (NLOS) applications in licensed and unlicensed bands from 2 to 11 GHz bands. To fill the gap between Wireless LANs and Wide Area Networks. WiMAX-compliant systems will provide a cost-effective fixed wireless alternative to conventional wire-line DSL and cable in areas where those technologies are readily available. The ongoing evolution of IEEE 802.16 will expand the standard to address mobile applications thus enabling broadband access directly to WiMAX-enabled portable devices ranging from smart phones and PDAs to notebook and laptop computers.

Nowadays, the rapid growth of high-speed multimedia services for residential and small business customers has created an increasing demand for last mile broadband access. Traditional broadband access is offered through digital sub- scriber line (xDSL) [5], cable or Tl networks. Each of these techniques has different cost, performance, and deployment trade-offs. While cable and DSL are already being deployed on a large scale, Fix Broadband Wireless Access systems are gaining extensive acceptance for wireless multimedia services with several advantages. These include avoiding distance limitations of DSL, rapid deployment, lower maintenance and upgrade costs, and granular investment to match market growth. Study group IEEE 802.16 has been formed under IEEE 802 to recommend an air interface for FBWA systems that can support multimedia services [6-8].

Compared with existing cellular systems, the main advantages of IEEE 802.16 are the longer transmission range and more sophisticated support for Quality of-Service (QoS) at the MAC level. Various applications and services type can be used in IEEE 802.16 networks and the MAC layer is designed to support this convergence. The standard will revolutionize broadband communications in developed countries and will allow the developing countries to be communicated to.

With this technology, the users will be able to have access to broadband networks anywhere and anytime. There are some competitive technologies such as third generation of mobile communications (3G) or HSPA but nowadays they only can provide high-data rates in small areas of coverage and under some specific conditions.

The IEEE802.16 standard defines two operational modes: the Point-to-Multi-Point mode and the mesh mode. The PMP mode defines one-hop communication between a base station and a subscriber station. It is designed to replace current last-mile technologies (e.g., xDSL). In the IEEE 802.16 (e) standard, the PMP mode supports mobility management and thus becomes a strong candidate for the next-generation telecommunication network. In the PMP mode, network nodes are divided into three types: PMP Base Station (BS), PMP Gateway Subscriber Station (Gateway SS), and PMP Host Subscriber Satiation (Host SS) nodes. As shown in Figure 1, a BS node is responsible for servicing several SS nodes. A SS gateway node can connect to a private subnet and is capable of routing packets from/to the connecting to it. In contrast, a PMP Host SS node is a network node equipped with an IEEE 802.16(d) PMP radio and can only connect to an IEEE 802.16 PMP [9].

2. The Framework and Mechanism for Mesh Mode

To serve fixed Subscribers (SS) through a base station using a PMP mode the IEEE 802.16 standard is presented. In IEEE 802.16-2004, the Mesh mode is introduced as an additional operating mode. As mentioned in the Section, the MSS are not directly connected to the base station MBS in IEEE 802.16 mesh mode. Thus, a Mesh base station (MBS) can support more Subscribers in the Mesh mode than the PMP mode. Thus, to reduce the number of MBSs that are needed to cover a given area. Mesh mode is more appropriate than the IEEE 802.16 PMP mode. IEEE 802.16e adds mobile user support to IEEE 802.16 networks. Unlike fixed SS, these mobile SSs have limited battery capacity unlike fixed SSs and they employ mechanisms to reduce power consumption such as the Sleep mode in IEEE 802.16e standard. However additional mechanisms are necessary to further increase battery life. Since MSSs do not need to be directly connected to the MBS, MSSs are able to connect to nearby MSSs instead of connecting directly to the MBS. The reduction of transmission distance will decrease the power consumption of the SS. Thus, with the introduction of IEEE 802.16e, the importance of the Mesh mode is increased considerably. In IEEE 802.16 Mesh mode, the frame is divided into two parts figure 2).

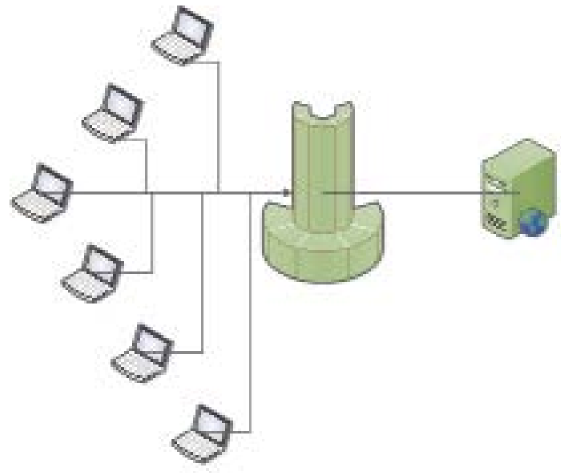

Figure 1. An Example of the IEEE 802.16 PMP Mode Network

The first part is the control sub-frame, in which network configuration and scheduling messages are sent. The second part, the data sub-frame, comprises of data bursts to and from MSSs and the MBS. The control sub-header can be either a scheduling control sub-header or a network control sub-header. The requests and grants for transmissions are sending by using scheduling control sub-frame (Figure 3). The second sub-frame is used less frequently. If there are topology changes in the network, the MBS is apprised about these changes in this sub-frame by the network configuration and entry messages sent by MSSs. Moreover, the MBS informs MSSs about data sub-frame usage until the frame with the next control sub-frame by sending the burst profiles (Figure 4).

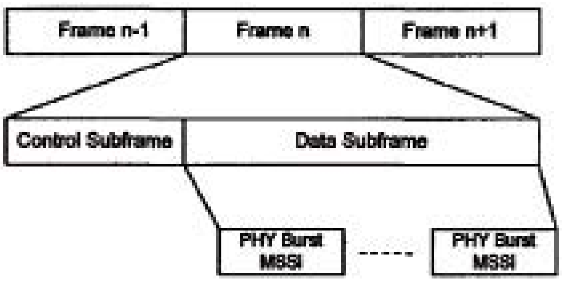

Figure 2. Frame Structure of the IEEE 802.16 Mesh mode

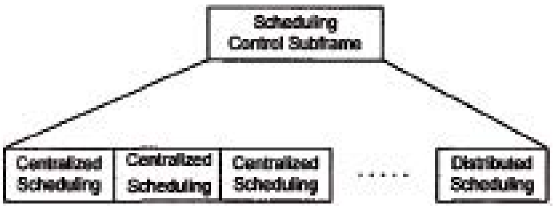

Figure 3. Scheduling Control Sub frame

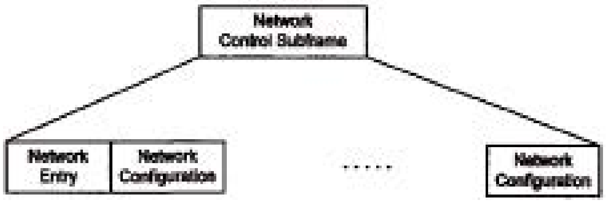

Figure 4. Network Control Sub frame

There are two frame scheduling methods in IEEE 802.16 Mesh mode: centralized scheduling and distributed scheduling. Distributed scheduling can be divided into coordinated distributed scheduling and uncoordinated distributed scheduling.

The difference of them is whether scheduling messages with collision. In the distributed scheduling method, nodes use a three-way handshake scheme for traffic scheduling. Each node transmits its current schedule and its recommended schedule changes (i.e. requests) to its one-hop neighbors. If the destination nodes grant a request, they respond to the source node in one of the mini-slots of the control sub-frame, which is also described in the request message. Finally, the source re-transmits the grant message to the destination for confirmation. The differences between the two distributed scheduling methods are the use of the control sub-frame for the scheduling messages. In the coordinated distributed scheduling, scheduling messages are sent in a collision-free manner, where the scheduling messages may collide in the uncoordinated distributed scheduling.

In the PMP Mode there are five service types specified and the request/grant mechanisms are different for each service type. Each connection in the network uses one of these five scheduling services. The UGS supports real-time T1/E1 services and CBR traffic. The rtPS supports real-time VBR traffic. The third service, nrtPS is providing for non-real-time traffic. The fourth service is BE traffic. The fifth scheduling service is included to the standard with IEEE 802.16e. In [10], Lee et al. have shown that the former four scheduling services described.

A UGS connection declares its average traffic usage to the MBS during connection establishment, and the MBS allocates exactly that amount of bandwidth in each frame, even if the bandwidth is not utilized. The second scheduling service, rtPS, uses dedicated periodic mini-slots in the uplink channel for sending its request to the MBS. nrtPS connections also use dedicated periodic request minimum-slots. Merely, the period for the allocation of dedicated requests is much longer for nrtPS connections than rtPS connections. nrtPS connections may also use contention based time mini- mini-slots to send their requests to the BS. These contention mini- mini-slots are also used by the BE connections. The ertPS scheduling service uses a request/grant mechanism similar to the one used for UGS connections. The difference is that the allocated bandwidth can be decreased (and increased back again) based on the presented traffic.

As mentioned above the QoS mechanism presented for IEEE 802.16 PMP mode can also be used in the IEEE 802.16 Mesh mode. Nevertheless, since all transmission between two nodes is managed by one link, this method cannot be applied in the IEEE 802.16 Mesh mode directly.

In the IEEE 802.16 Mesh mode, each MSS is allocated a node ID upon connection establishment. In our solution, NPQoS, the MBS assigns five node IDs instead of one node ID to each MSS. These five nodes represent the five service classes' types as explained in Figure 5. Each node will request a bandwidth in an individual form, and the MBS handles these requests according to their scheduling services. For UGS scheduling services, the first Virtual node (MSS1) is used. This node requests bandwidth once after connection establishment and then MBS alto-Gates the requested amount of bandwidth in each frame. The ertPS service is represented by the second Virtual node (MSS2). The request/grant mechanism used for this node is similar to the one used for the UGS node. However, unlike the UGS node, the ertPS node may send requests to the MBS after connection establishment to reduce and increase its allocated size up to its maximum sustained allocation limit. For rtPS and nrtPS services the third and fourth Virtual nodes respectively are used. Despite both of them use the default request/grant messaging of the Mesh mode, an nrtPS node cannot send a request message in each

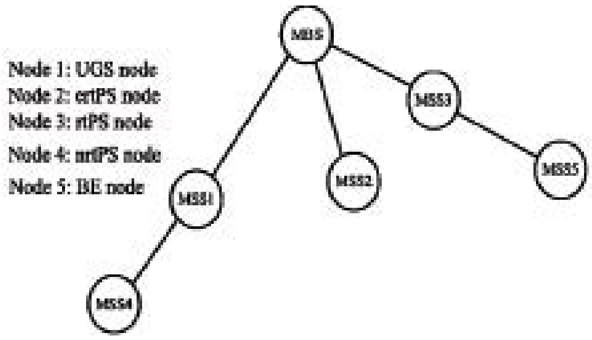

Figure 5. Virtual Nodes

frame. It can only send its requests in one flame in a given number of frames (nrtPS Poll Interval). For BE services the fifth Virtual node is used. It can use collision-based mini-slots in the scheduling control sub-header to send its request messages.

3. Novel Base Station Scheduling (NBSS) Algorithm

In the mesh mode, scheduling is one of the most important factors that will impact the system performance. Therefore; there are several studies on MBS' scheduling in IEEE 802.16 Mesh mode. However, traffic demand of MSSs in terms of priority basing on granted transmission time is not discussed in these studies.

In previous scheduling algorithms, each potential transmission is assigned a time mini-slot in such a way that the higher priority is given to MSS with higher traffic demand. Thus, MSS with high traffic demand occupies long scheduling period and causes large delay time of the MSS with lower traffic demand.

Service differentiation is needed for different applications. The differentiation can be achieved by assigning different priorities to the traffic flow and scheduling packet transmission based on the priority of the associated traffic class. For instance, VoIP traffic can be given a higher priority so that it has a greater probability of obtaining channel access and subsequently meeting its end-to-end delay fitter requirements. On the other hand, non-real-time traffic can be given lower priority.

To provide hybrid differentiated services based on the nodes traffic demand and priority-based scheduling (PBS) of each MSS. Taking special considerations on average delay time and number of served nodes NBSS is proposed. NBSS makes scheduling decisions based on traffic demand of each MSS. in which case the node with the low traffic demand and high traffic class is given a relatively higher priority. The experimental results show that NBSS has high throughput, a reduction in delay time for each MSS and can serve more number of users.

In IEEE 802.16 Mesh mode, the traffic is mainly to and from the BS, thus we focus on MBS scheduler algorithm. The centralized scheduler can provide a traffic allocation scheme for each MSS such as that traffic can reach its destination in the scheduling period. Thus, increasing the number of served nodes and decreasing the average delay time become the important objects in the design of scheduling algorithm.

For example, node G has a 2ms traffic demand, which means that node G require 2ms to use the transmission channel. As shown in Figure 6, the time request of node A, which is equal to 5ms, is the sum of traffic demand in nodes A, G, H. The six nodes A, B, C, D, E and Fin the first-level of network tree have requests of 5, 20, 5, 5, 5 and 20ms respectively. We assume the priority services of these nodes are 0.3, 0.6, 0.55, 0.2, 0.4, and 0.5 respectively. Each of these nodes collects the request time from its sub-tree. The total time given to these nodes, which can be allocated in node MBS, is 40ms.

In this example, the total number and the delay time of served nodes in NBSS, Random and PBS are investigated. In Random method, all nodes are randomly sorted and the node that sends request first will be scheduled first. In priority-based scheduling method, all nodes are sorted by their priority service in decreasing order. Figure 7 shows the served order of NESS, Random, and PBS methods.

$$\hat{f}_H^{\alpha}(x) = \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} \frac{f(t)}{(t-x)^{\alpha}} (dt)^{\alpha}$$
$$= \frac{1}{\Gamma(1+\alpha)} \int_{-\infty}^{\infty} f(t) g(x-t)(dt)^{\alpha} = f(x) * g(x), \qquad (1)$$

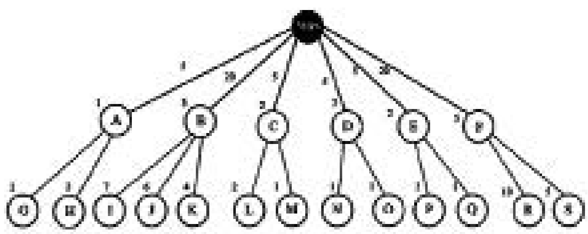

Figure 6. Network Topology

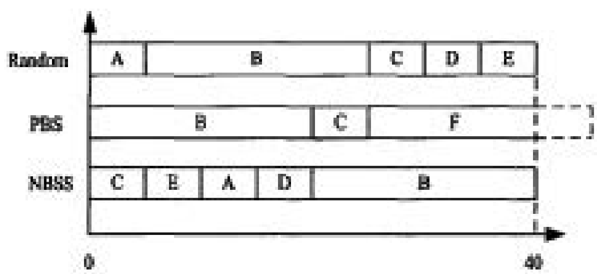

Figure 7. Served order of NBSS, Random and PBS methods

The equation is as follows:

$$\partial_j (C_{ijkl}\partial_k u_l + e_{kij}\partial_k \varphi) - \rho \ddot{u}_i = 0 \quad (2)$$

Under the linear theory, that is:

$$\partial_j (e_{ijkl}\partial_k u_l - \eta_{kij}\partial_k \varphi) = 0 \quad (3)$$

The linear equation can be expressed into the following simplified forms:

$$L(\nabla,\omega) f(x,\omega) = 0 \,,\ L(\nabla,\omega) = T(\nabla) + \omega^2 \rho \mathrm{J} \quad (4)$$

In which,

$$T(\nabla) = \begin{Vmatrix} T_{ik}(\nabla) & t_i(\nabla) \\ t_k^T(\nabla) & -\tau(\nabla) \end{Vmatrix},\ \mathrm{J} = \begin{Vmatrix} \delta_{ik} & 0 \\ 0 & 0 \end{Vmatrix},$$

$$f(x,\omega) = \begin{Vmatrix} u_k(x,\omega) \\ \varphi(x,\omega) \end{Vmatrix} \quad (5)$$

Consider delay, the L can be expressed as:

$$L^0 = \begin{Vmatrix} C_{ijkl}^0 & e_{kij}^0 \\ e_{ikl}^{0T} & -\eta_{ik}^0 \end{Vmatrix} \quad (6)$$

These functions can be expressed in the following form:

$$C(\mathrm{x}) = C^0 + C^1(\mathrm{x}) \,,\ e(\mathrm{x}) = e^0 + e^1(\mathrm{x}) \,,$$

$$\eta(\mathrm{x}) = \eta^0 + \eta^1(\mathrm{x}) \,,\ \rho(\mathrm{x}) = \rho_0 + \rho_1(\mathrm{x}) \quad (7)$$

The value with superscript of 1 represents the difference below:

$$C^1 = C - C^0 \,, e^1 = e - e^0 \,,$$

$$\eta^1 = \eta - \eta^0 \,, \rho_1 = \rho - \rho_0 \quad (8)$$

Based on above description of the algorithm, the pseudo-code of our algorithm is shown in Figure 8.

```
Input: n← MSSs;
     K ← the first-level nodes count;
     mi← count of nodes whose data passes through node i.
     a ←Network topology as structure;
Output: Allocate bandwidth to each MSSs←  abwi;
        Allocate priority for first level nodes← Pi
for (i=1; i<= n; i++) do
 {rgi=1/gi
  p=p+rgi
  tri=Ci×gi
 }
for (i=1; i<= K; i++) do
  {for (j=1;j<=mi;j++) do
     {  Tri=Tri+trmij
          Tri=Tri+tri
     }
   abwi=Tri×rgi
   Pi=(rgi/p )×Npi
 }
```

Figure 8. Pseudo Code for the NBSS Algorithm

Conclusions

In this paper, NBSS algorithm is proposed. NBSS makes scheduling decisions based on traffic demands and priority-based scheduling for each MSS node in the IEEE 802.16 mesh network. The presented formulas and the algorithms are not computationally expensive. Thus, the scheduler will not burden the BS with extensive calculations.

Simulation results show the delay of three methods. Considering the delay time is from MBS to the correspondent node. Obviously, NBSS is suitable to serve a large number of users and decreases the delay time for each MSS. Using NBSS, we can limit the delay time for each request of MSSs in IEEE 802.16 mesh mode.

In our further studies, we will consider making our scheduling more flexible to meet QoS requirements. This paper investigates the BS Centralized scheduling for IEEE 802.16 mesh network, it also present NBSS algorithm which is a hybrid differentiated services based on the nodes traffic demand and priority-based scheduling (PBS) of each MSS, and compares NBSS, PBS, and Random methods.

Three methods are compared in various aspects including delay time, the number of served nodes, and Network throughput. Simulation results show the delay of three methods. Considering the delay from the BS to the correspondent node, it is clear that NBSS is suitable to serve a large number of users and decreases the delay time for each MSS. Using NBSS, we can limit the delay time for each request of MSSs in IEEE 802.16 mesh mode. In our further studies, we will consider making our scheduling more flexible to meet QoS requirements.

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Study on Video Fingerprint Algorithm Based on Luminance Structured Quality Assessment

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Abstract
This paper focuses on research about feature extraction, fingerprint modeling and similarity matching of video fingerprinting. Three digital video fingerprint algorithms are presented in this paper. A fingerprint algorithm based on relative orientation invariant between geometric centroid is suggested. The perceptual centroid means that the same perceptual content video should have the same centroid, further, the orientation of the centroid is identical, and the relative orientation keeps unchangeable. In this method, the geometric center of every frame is used as original point and the orientation of centroid is calculated based on luminance geometric centroid. Converting orientation from the original frame rate to a fixed frame rate through temporal distance and a new orientation vector