Research on the Multi-channel Assignment Algorithm Based on Greedy Algorithm for Wireless Mesh Networks

Xin Wang (corresponding author*)

1 School of electric & information
Lanzhou Jiaotong University, Lanzhou. China
2 China Academic of Railway Science, China

***Abstract* — In this paper, the author researches on the multi-channel assignment algorithm based on greedy algorithm for Wireless Mesh Networks. 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. To fill the gap between Wireless LANs and Wide Area Networks. WiMax-compliant systems provide a cost-effective fixed wireless alternative to conventional wire-line DSL and cable in areas where those technologies are readily available.**

Keywords - multi-channel assignment algorithm; greedy algorithm; wireless mesh networks.

I. 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, Hiper LAN, Home RF, and WiMax. Each technique has its own niche depending on the deployment requirements.

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 [1-2]. 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 subscriber line (xDSL), 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 [3]. Study group IEEE 802.16 has been formed under IEEE 802 to recommend an air interface for FBWA systems that can support multimedia services.

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 [4-5].

With this technology, the users will be able to have access to broadband networks anywhere and anytime [6]. 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. 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 subnet connecting to itself. 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 network.

IEEE 802.16 mesh mode, which is designed for constructing a backbone network. The MBS node is a gateway device connecting a fixed network with the mesh network which it services. It is also responsible for processing network registration requests from MSS nodes. A mesh SS node can be used as either an end-user device (MSS Client Node) or a hot-spot access point (MSS Forwarder Node). Besides, a MSS node (MSS Gateway Node) can be used as a gateway connecting a mesh backbone network and a private network. In the mesh mode, the control-plane bandwidth is divided into transmission opportunities and the data-plane bandwidth is divided into mini-slots. Both of the transmission opportunity and the mini mini-slot are fixed-length time-division period that transmits control messages and data packets, respectively. The mesh mode has three scheduling modes: centralized scheduling, distributed coordinated scheduling, and distributed uncoordinated scheduling.

II. THE FRAMEWORK

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 [7]: 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 [8].

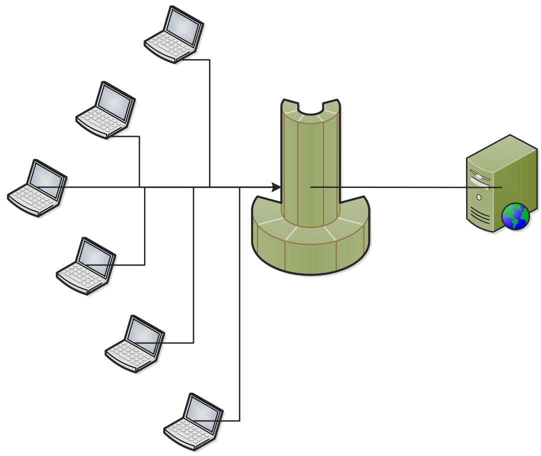

Figure 1. An Example of the IEEE 802.16 PMP Mode Network.

Transmission opportunities are assigned to logical channels. There are three types of logical channels: basic, broadcast and data. The basic channel is used for ranging and network entry packets, the broadcast channel is used to transmit mesh control packets, and the data channels are used for data packets and some IEEE 802.16 control packets. The basic channel is allocated in the control sub-frame. Some slots used by the broadcast channels are in the control sub-frame and some are in the data sub-frame. All data channel slots are located in the data sub-frame.

The basic channel and the data channels are unicast since only one node is supposed to process transmissions from the channel, while the messages in the broadcast channel are intended for all first-hop neighbors of a node. Three types of broadcast channels are depending on how transmission opportunities in the channel are shared. There are two reliable broadcast channels that use transmissions to prevent collisions. The first uses distributed election based scheduling for MSH-NCFG and MSH-DSCH messages. The second uses tree based scheduling for MSH-CSCH and MSH-CSCF messages. Optionally, MSH-DSCH messages can also be transmitted in the unused data slots of the data sub-frame, in an additional unreliable broadcast channel. We elaborate on the purpose of each of the control packets further in the rest of the section. Figure 2 shows the OFDM to achieve TDMA in IEEE 802.16 WNN and figure 3 shows placement of logical channels in the frame.

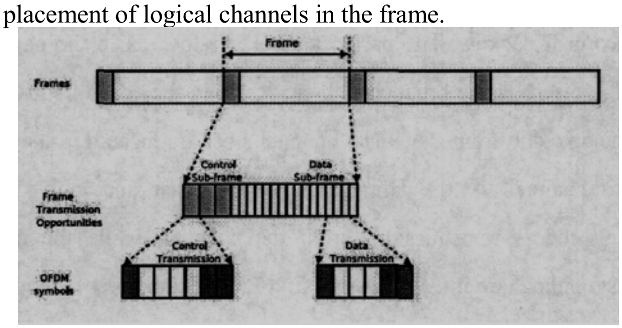

Figure 2. OFDM to achieve TDMA in IEEE 802.16 WNN.

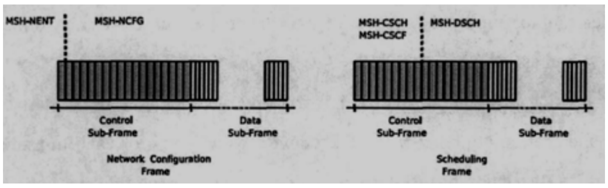

Figure 3. Placement of logical channels in the frame.

III. THE MSH-NCFC STRUCTURE

Network configuration messages, MSH-NCFC, and coordinated distributed scheduling messages, MSH-DSCH, use broadcast channels with distributed election scheduling. In distributed election scheduling, each transmitter sharing the channel broadcasts the range of opportunities it considers for transmissions. The transmitters whose ranges of transmission opportunities overlap with their two-hop neighbor's ranges perform a distributed election procedure for each transmission opportunity. The election algorithm guarantees that each transmission opportunity has only one winner, so that the transmissions in the channel are collision-free.

Given the index of a transmission opportunity in the channel, Current TxOpp, the frame in which the transmission should take place can be found in dividing Current TxOpp by the number of network configuration transmission opportunities in each frame, MSH-CTRL-LEN-l, and then multiplying by the number of frames between successive network configuration frames.

By subtracting the number of transmission opportunities before the start of the frame and then multiplying by 7 to account for the length of each transmission opportunity, the index of the starting OFDM symbol for the transmission can be found.

The distributed scheduling broadcast channel is located in the last 7X MSH-DSCH-NUM OFDM symbols of the control scheduling sub-frames, after the centralized scheduling messages in figure 4. MSH-DSCH-NUM is a network parameter indicating the number of transmission opportunities in the control sub-frame allocated to distribute scheduling messages.

As with the MSH-NCFG channel, the transmission opportunities in the distributed scheduling channel can be viewed on their own axis in figure 5. Given the index of a transmission opportunity in the channel, Current TxOpp, the frame in which the index of the starting OFDM symbol can be found by subtracting the number of transmission opportunities before the start of the frame and then adding the number of OFDM symbols used for the centralized scheduling channel.

In both the network configuration and distributed scheduling broadcast channels, transmission opportunities are assigned with the use of a distributed election algorithm. The distributed election algorithm specified in the IEEE 802.16 mesh standard works in two parts. First, the nodes exchange the range of transmission opportunities they consider for transmission. Second, the nodes contending for the same transmission opportunity perform an election to decide who should transmit during the conflicting transmission opportunity. The election procedure uses a combination of the conflicting transmission opportunity index and each of the conflicting node identifiers to create a unique, pseudo-random, 16-bit hash value. The node with the highest 16-bit hash value for the transmission opportunity wins the election.

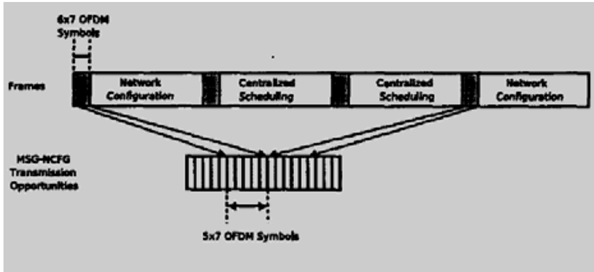

Figure 4. 7X MSH-DSCH-NUM OFDM symbols of the control scheduling sub-frames.

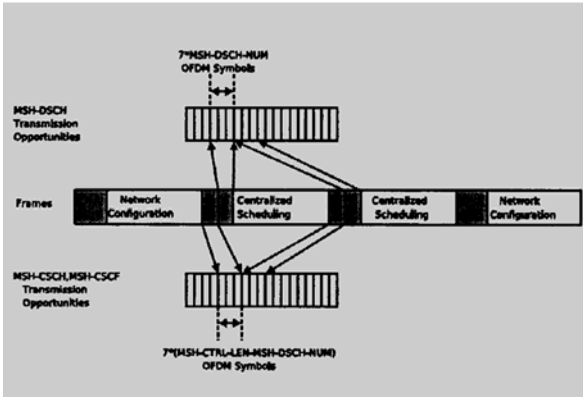

Figure 5. Transmission opportunities of The MSH-CSCH, MSH-CSCF and MSH-DSCH.

IV. THE DISTRIBUTION ALGORITHM AND RESULT

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.

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

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

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:

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

In which,

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

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

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:

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

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

The value with superscript of 1 represents the difference below:

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

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

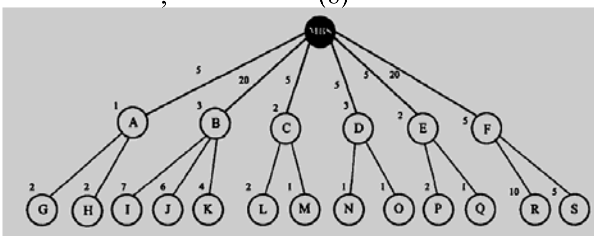

Figure 6. Network Topology.

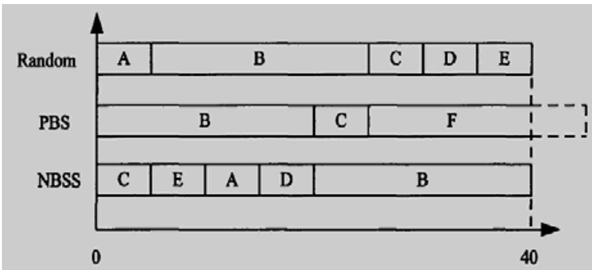

Figure 7. Served order of NBSS, Random and PBS methods.

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;
    m_i← count of nodes whose data passes through node i.
    a ←Network topology as structure;
Output: Allocate bandwidth to each MSSs← abw_i;
        Allocate priority for first level nodes← P_i
1: for (i=1; i<= n; i++) do
2:   { rg_i=1/g_i
3:     μ=μ+rg_i
4:     tr_i=C_i×g_i
5:   }
6: for (i=1; i<= K; i++) do
7:    {for (j=1;j<=mi;j++) do
9:        {   Tr_i=Tr_i+tr_ai,j
10:               Tr_i=Tr_i+tr_i
11:       }
12:    abw_i=Tr_i×rg_i
13:    P_i= (rg_i/μ ) ×Np_i
14: }
```

Figure 8. Pseudo Code for the Algorithm.

V. CONCLUSIONS

In this paper, the author researches on the multi-channel assignment algorithm based on greedy algorithm for Wireless Mesh Networks. 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.

Three types of broadcast channels are depending on how transmission opportunities in the channel are shared. There are two reliable broadcast channels that use transmissions to prevent collisions. The first uses distributed election based scheduling for MSH-NCFG and MSH-DSCH messages. The second uses tree based scheduling for MSH-CSCH and MSH-CSCF messages. Optionally, MSH-DSCH messages can also be transmitted in the unused data slots of the data sub-frame, in an additional unreliable broadcast channel. To fill the gap between Wireless LANs and Wide Area Networks. WiMax-compliant systems provide a cost-effective fixed wireless alternative to conventional wire-line DSL and cable in areas where those technologies are readily available.

ACKNOWLEDGEMENTS

This work is supported by the Key Project of Guangxi Social Sciences, China (No.gxsk201424), the Education Science fund of the Education Department of Guangxi, China (No.2014JGA268), and Guangxi Office for Education Sciences Planning, China (No.2013C108).

REFERENCES

[1] J.J. Garcia Adeva, J.M. Pikatza Atxa, M. Ubeda Carrillo et al. Automatic text classification to support systematic reviews in medicine. Expert Systems with Application, 2014, 41(4 Pt.1), pp. 1498-1508.

[2] Ricardo Nanculef, Ilias Flaounas, Nello Cristianini et al. Efficient classification of multi-labeled text streams by clashing. Expert Systems with Application, 2014, 41(11), pp. 5431-5450.

[3] Jiali Yun, Liping Jing, Jian Yu et al. A multi-layer text classification framework based on two-level representation model. Expert Systems with Application, 2012, 39(2), pp. 2035-2046.

[4] Changxing Shang, Min Li, Shengzhong Feng, Qingshan Jiang, Jianping Fan. Feature selection via maximizing global information gain for text classification. Knowledge-Based Systems, 2013, pp. 54-68.

[5] Zhi-jian QU, Yin-bao XIE, Ju-hui WANG, Xiao-hong LIU. Design of a node architecture for logic-calculation Nased all-optical network coding scheme. The Journal of China Universities of Posts and Telecommunications, 2013, pp. 205-215.

[6] Lijun Li, Rentao Gu, Yuefeng Ji, Lin Bai, Zhitong Huang. All-optical OFDM network coding scheme for all-optical virtual private communication in PON . Optical Fiber Technology, 2013, pp. 13-27.

[7] Kaikai Chi, Yi-hua Zhu, Xiaohong Jiang, Xianzhong Tian. Practical throughput analysis for two-hop wireless network coding. Computer Networks, 2013, pp. 233-256.

[8] Luiz Filipe M. Vieira, Mario Gerla, Archan Misra. Fundamental limits on end-to-end throughput of network coding in multi-rate and multicast wireless networks. Computer Networks, 2013, pp. 5717-5727.