Design of Group Transmission Scheme in IEEE 802.16 PMP Network

Yi-Ting Mai, Jeng-Yueng Chen

Abstract

IEEE 802.16 Wireless Network technology has been a hot research issue in recent years. It provides wider coverage for radio and higher speed wireless access. Quality of Service also plays an important part in the standard. As one of the promising techniques in Broadband Wireless Access (BWA), IEEE 802.16, also called WiMax, provides non-line-of-sight wireless transmission to support multimedia services. It is an appropriate solution for large area network deployment. The IEEE 802.16 network can provide last-mile technology for end user Internet connections. On the other hand, to achieve multimedia service such as VOD or Online TV, IP Multicast is an efficient technology. IP Multicast is a one-to-many delivery mechanism that is useful for efficiently distributing data to interested listening hosts at arbitrary locations on the Internet. Considering the rare wireless bandwidth in the IEEE 802.16 network, the conception of IP Multicast is an appropriate idea for multiple connections in the same traffic. Therefore, this study designs an integrated scheme to combine 802.16 connections with IP Multicast traffic. This scheme can reduce bandwidth usage and signal cost in an IEEE 802.16 PMP network. Simulation studies have shown that the proposed scheme has lower bandwidth consumption and signal cost than current technologies.

Keywords: IEEE 802.16, IP Multicast, Multimedia, WiMax, Wireless Network.

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群組傳播機制運作於 IEEE 802.16 PMP 網路之設計

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摘 要

IEEE 802.16 無線網路技術是近年來相當熱門的研究議題，它提供了更大的訊號涵蓋範圍與更高速的無線傳輸服務，而 Broadband Wireless Access(BWA)的技術提供了更高速、更便利及無線上網的服務，也開啓了新無線網路的世代。IEEE 802.16 網路其技術可以讓無線網路傳輸的距離可以長達 50 公里並支援 134 Mbps 的頻寬。因此 802.16 的高頻寬也將能夠提供大範圍無線網路一個良好的多媒體服務架構。在此無線網路環境之下，多媒體的運用將會更加重要與普及，然而大範圍的網路也將面臨大量多媒體使用者存取資源的問題，如何讓頻寬可以更有效的利用，這將是一個需要思考的問題。在傳統有線網路上的 IP Multicast 技術，可以用來傳送多媒體資料給相同的使用者，此技術運用在 Internet 及 802.16 無線網路上，將可以提供有效的網路傳輸。然而現有的研究中都沒有一併將 802.16 網路當成一個 Multicast tree 的一部分進行討論，面對 BS, SSs 所組成的 802.16 網路時，802.16 網路內仍然採用 Multiple unicast 的方式來進行多使用者的傳輸，因此我們提出一個簡單 IP Multicast 管理機制在 802.16 網路上，將可以有效的使用頻寬，進而提供更多的使用者可以同時使用多媒體服務，同時也可以在 802.16 無線網路環境之下達成無線網路多媒體服務的實現與效能提昇。

關鍵詞：802.16、PMP、網路層多點傳播、多媒體服務、無線網路。

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1 Introduction

The IEEE 802.16 standard is one of the most popular wireless standards developed recently. It enables high-speed data transmission (up to 134 Mbps) and has a wide coverage area (from 10 km to 50 km). The IEEE 802.16d [1] standard proposed in 2004 had a network architecture composed of a BS (base station) and several SSs (subscriber stations). Moreover, this standard facilitated the design of a network with PHY and MAC layers and QoS support at the MAC layer for multimedia applications. Furthermore, the IEEE 802.16e [2] standard proposed that SSs can have mobility in a large wireless network.

IP Multicast is used for efficient transport of large amounts of data to a group of users. When transmission data to a group of users, new users can join and existing users can leave the group, which continues to receives the same resources. For delivering data to multiple users over the Internet, it is necessary to construct or manage a multicast group from a multicast tree on the basis of signal messages, as is the case with the *IGMP* [3] protocol. Since IEEE 802.16 is specific to L1 and L2 and the BS serves as a domain gateway, it is regarded as a large *LAN (local area network)* in the 802.16 domain. Therefore, during multicast traffic transmission, the BS only employs local broadcasting as the IP Multicast scheme. Thus, the BS is regarded only as a router on a multicast tree when operating an IP Multicast scheme. However, in the IEEE 802.16 network, every L3 flow is mapped to an 802.16 connection and owns the ID of the *connection identifier (CID)* corresponding to itself. Multicast traffic has not been clearly defined in the IEEE 802.16 standard. A future study will investigate this issue from the viewpoint of achieving efficient multicast traffic delivery. In this study, we attempt to identify the relation between the members of a multicast group in the IP and MAC layers of the IEEE 802.16 network so as to determine an efficient approach to realize multicast traffic flow through an IEEE 802.16 *point-to-multipoint (PMP)* network.

Chapter 2 provides an introduction to IEEE 802.16 PMP networks. Our proposed scheme is explained in Chapter 3. Chapter 4 presents simulation results that demonstrate the good performance of our proposed scheme, and Chapter 5 provides our conclusions

2 Related Work

2.1 IEEE 802.16 PMP Network

IEEE 802.16 [1] facilitates the development of a *broadband wireless access (BWA)* system, and its main purpose is to define an operating scheme for the PHY and MAC layers. It not only solves the last mile problem but also effectively reduces the cost of setting up a network. As shown in Fig. 1, the PMP configuration in an IEEE 802.16 network consists of a BS and a couple of SSs that connect to the BS via high-speed wireless links. The BS acts as a gateway to the Internet. Legacy LANs or even more complex subnet systems can connect to the IEEE 802.16 network via an SS. The IEEE 802.16 network (including the legacy LANs that connect to an SS), which was designed to support multimedia services by enabling QoS support of different types of services, can cover a large geographical area since the distance between the BS and an SS can be up to 30 miles [1]. Some articles on QoS support systems [4]-[6] have discussed cross-layer (L3 and L2) in IEEE 802.16 network.

Because the BS is the controller in the IEEE 802.16 PMP network, its design involves two different transmission directions, as shown in Fig. 2. There are two basic transmission modes in IEEE 802.16: *time division duplex (TDD)*, as shown in Fig. 3, and *frequency division duplex (FDD)*, as shown in Fig. 4. The TDD mode permits simultaneous downlink and uplink transmission over the same wireless channel. Downlink transmission is simple because only one BS broadcasts data to all SSs during the period of a downlink subframe, and an SS receives only the data that belongs to its minislots. However, in uplink transmission, each SS must send a message to the BS through a *bandwidth request (BW_REQ)* signal, and the BS then decides the number of minislots for every SS. Hence, every SS is only allowed to transmit data to the BS through unicast transmission during the uplink subframe. However, the administrator needs to divide time among many users because they cannot send data simultaneously. In contrast, the FDD mode enables the allocation of separate bandwidths for downlink and uplink transmission so that users can simultaneously transmit and receive data.

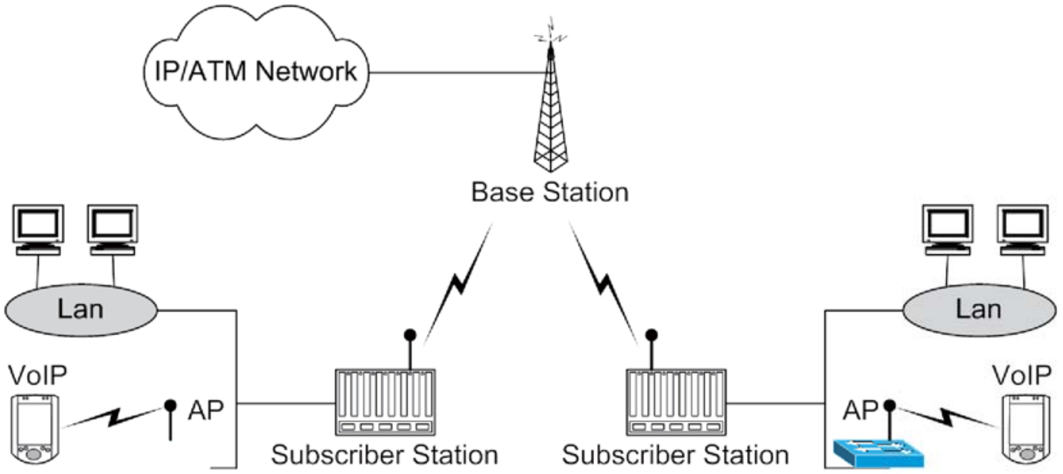

Fig. 1. IEEE 802.16 PMP network

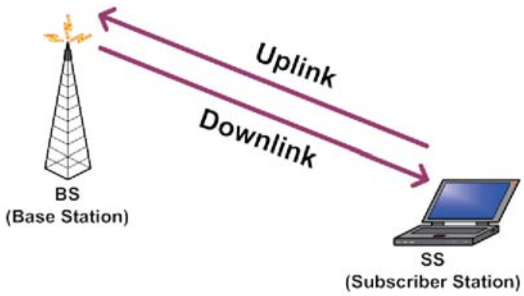

Fig. 2. Uplink and downlink mode

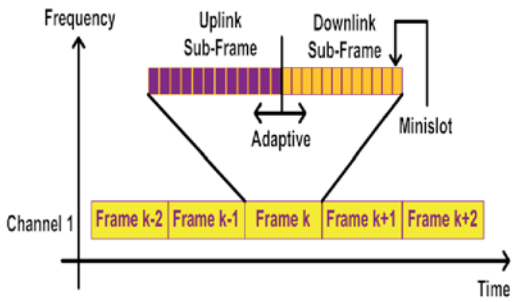

Fig. 3. TDD time frame structure

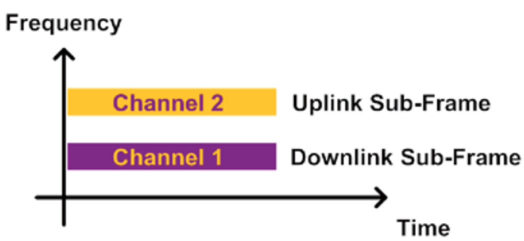

Fig. 4. FDD time frame structure

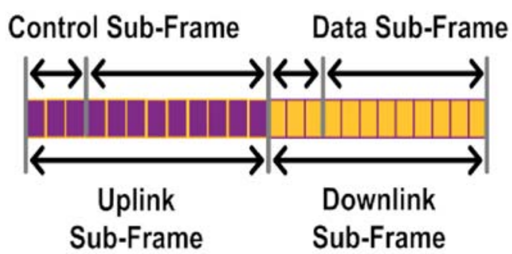

Fig. 5. Control and data sub-frame structure

2.2 Multicast Scheme in IEEE 802.16

Although various IP Multicast schemes have been proposed over the years, many studies have also focused on enabling access to the Internet through wireless networks. Most of these studies have examined the manner in which *mobile IP (MIP)* integrates with *IP Multicast* [7]. Under the situation, we can classify two types to receive Multicast stream according to different ways which mobile host (MH) joins. There are two MIP Multicast schemes, namely, *Remote Subscription* (*RS*) [8] and *Bi-directional Tunneling* (*BT*) [9]. In addition, many of studies have investigated IP Multicast applications in different wireless networks such as *WiFi* [10], and *3G* (*UMTS* [11], *CDMA2000* [12]). Some researches aim to achieve multicast transmission by utilizing MHs in the IEEE 802.16e standard [13]-[14]. On such study [15] compares the efficiencies of two services—broadcast and multicast polling—when subject to an SS request in the IEEE 802.16 PMP network. However, no study has explicitly addressed the issue of integration of IP Multicast group transmission in IEEE 802.16 PMP networks.

According to the specifications of IEEE 802.16d, every flow has an identification CID for a data transmission schedule. However, many users (inside the same 802.16 domain) require the same data; therefore, this data should be transmitted simultaneously to different users in the IEEE 802.16 PMP network.

Furthermore, every SS can integrate with different traffic flows and send a bandwidth request by multicasting. Moreover, if there is a characteristic-related flow among SSs, multicasting is also used to transmit data and communicate with the BS. SSs can receive data from the BS or join a multicast group through a *multicast assignment request (MCA_REQ, Fig. 6)*. At the same time, the BS can use the *multicast assignment response (MCA_RSP, Fig. 7)* as a reply. Thus, we can construct a multicast group between SSs and the BS. In IEEE 802.16d, the issues of integration and correspondence with presently used IP Multicast technology have not been clearly defined. Therefore, we intend to determine an approach to make IP Multicast technology circulate smoothly in Internet and IEEE 802.16 when transmitting data.

3 IP Multicast scheme in IEEE 802.16

The IP Multicast system [16][17] sets up a multicast group among users when they need to receive the same data together. Since all the users in the group receive the same data, we can devise a route agreement to enable routers to directly match the requirements of different users. In this manner, a high transmission efficiency can be realized for the entire network, as shown in Fig. 8 and Fig. 9.

A network will have maximum efficiency and make good use of the Internet bandwidth if we combine an IP Multicast scheme with routing. Nevertheless, for implementing an IP Multicast scheme on the Internet, it is necessary to preserve multicast trees through a route agreement. The present route agreement relies on technologies such as *DVMRP* [18], *MOSPF* [19], *CBT* [20], *PIM* [21][22]. In addition, the BS has L 3 capabilities and serves as the router in IEEE 802.16 networks. Moreover, the BS not only controls multicast group information but also decide them to accede to Multicast tree in 802.16 networks.

Management Message Type (8)	Transact ion ID
(16)	
TLV Encoded Information (variable)	

Fig. 6. MCA_REQ format

Management Message Type (8)	Transact ion ID
(16)	Confirmation Code (8)

Fig. 7. MCA_RSP format

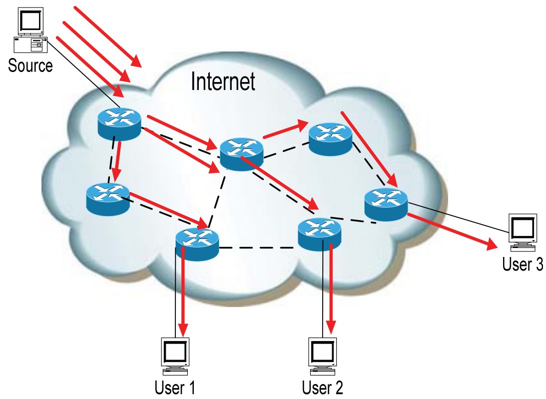

Fig. 8. Unicast transmission

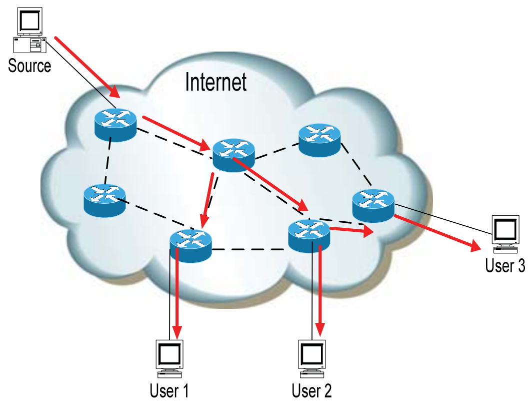

Fig. 9. Multicast transmissio

3.1 Multicast Group in IEEE 802.16

Generally, when an L3 flow is formed in IEEE 802.16 networks, it makes a connection and is assigned a corresponding CID. In multicast group transmission, many users want to access the same data resources and the same server. If we ensure correspondence between IP Multicast and CID, the BS only needs to transmit data to all SSs once.

In an IEEE 802.16 PMP wireless network, although the BS transmits data to SSs by TDM unicasting, for the physical layer, data transmission is achieved by broadcasting. All SSs can receive a wireless signal when the BS transmits data to any SS by unicasting. Hence, we attempt to add group information by using the *downlink map (DL_MAP)*, it could be more efficient and flexible for BS to distribute and exploit on time frame utilization. Taking into account multicast group transmission, we must maintain a connection record. We present a detailed approach to individually manage the users joining and leaving a multicast group.

Case 1: Multicast user joining the group

1. *User 1* sends a joining message to the BS via *SS_1*, and we record the IP of Class D in *SS_1*, as listed in Tab. 1.
2. In Tab. 2, *SS_1* sends an MCA_REQ message to the BS for joining the multicast group *M1*. If *SS_1* is joining the multicast group for the first time, the BS will decide that *SS_1* becomes the group manager and marks it in Tab. 2. For managing the multicast group state, *SS_1* should send the refresh control signal to maintain the group information.
3. If *SS_1* is also the leader SS in the multicast group, it will be informed when MCA_RSP message is received. Then, the basic SS receives the corresponding CID of the multicast from the MCA_RSP message to which the BS replies.
4. In general, the BS is a router and tree node in an IP Multicast group. Therefore, it will adopt a special corresponding CID of the multicast group to transmit data after it receives multicast data. If it receives data as unicast traffic, it will make the original CID, which belongs to its flow, transmit data.

Case 2: Multicast user leaving the group

1. When a user does not want to receive data from a multicast sender, that is, when a user wants to leave the multicast group, the user only needs to inform the SS to which he/she is connected.
2. When the SS receives a leaving message, it deletes the user's record. If the user's data is the last record in that multicast group, the SS must inform the BS that the SS will be leaving the multicast group.
3. After receiving a leaving message from the SS, the BS must confirm whether the SS is the leader of the multicast group. If the SS is the leader, the BS must choose the SS having the smallest ID (e.g., *SS_1*) as the new leader and inform it of the leaving message. Then,

the BS replies to the SS and deletes its record.

4. After receiving a confirmation message from the BS, the SS must delete user data from its multicast group table.

4 Performance Evaluation

4.1 Simulation Architecture

We designed a simulation experiment to determine the efficiency of integrating IP Multicast into an IEEE 802.16 network scheme. The aim of our simulation was to assess the effect of multicast flows on the performance of IEEE 802.16 PMP networks. In the simulation, we varied the number of SSs connected to one BS and the number of multicast group users belonging to a particular SS. When integrating IP Multicast into 802.16 networks, we used two performance criteria, namely, bandwidth utilization (average usage BW) and the number of multicast group control signals, to determine the transmission efficiency. Some simulation parameters are listed in Tab. 3. Furthermore, the simulation architecture (Fig. 10) shows that the source of a multicast group is outside the scope of the IEEE 802.16 network and all the multicast group members are within the coverage area of the SSs. We varied the number of SSs and the number of multicast group members separately in order to understand the performance of our proposed scheme.

Tab. 1. Multicast user group mapping information in SS_1

Multicast member's ID	IP address	Class D address	L2 CID
User1	163.17.75.1	224.2.2.10	FF00
User2	163.17.75.2	224.2.2.20	FF00
User3	163.17.75.21	224.2.2.30	FF03
User4	163.17.75.22	224.2.2.40	FF03

Tab. 2. Multicast user group mapping information in BS

SS's ID	L2 CID	Multicast group
SS_1*	FF00	M1 (224.2.2.4)
SS_3	FF00	M1 (224.2.2.4)
SS_2	FF01	M2 (224.2.3.4)
SS_3*	FF01	M2 (224.2.3.4)
SS_5	FF01	M2 (224.2.3.4)

Tab. 3. Simulation parameters

Item	Value
Total Bandwidth (Downlink)	20 Mbps
MAC Frame Size	20 ms
Simulation Time	100 sec
Multicast flow	CBR, 50 kbps
Multicast group size	16~256
# of BS	1
# of SS	2~32

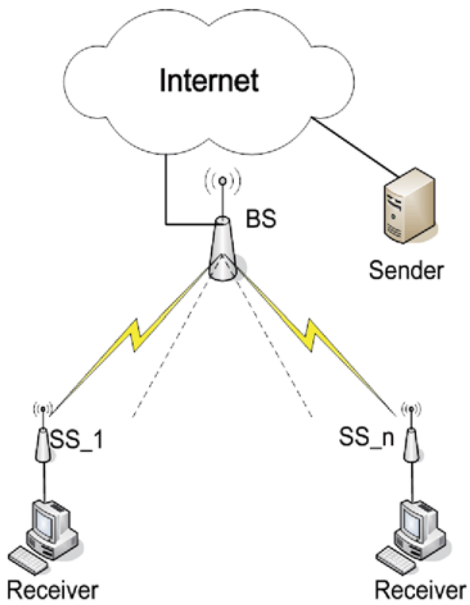

Fig. 10. Simulation architecture

4.2 Simulation Results

Fig. 11 and Fig. 12 show the average bandwidth usage in IEEE 802.16 networks when downloading information. Fig. 13 and Fig. 14 show the number of control signals sent by SSs to the BS. In Fig. 11 and Fig. 13, the total number of multicast group members is 64, while in Fig. 12 and Fig. 14, the number of SSs connected to a BS is 8. In Fig. 11, we find that the traditional way in 802.16 networks only corresponds to CID according to original L3 flow individually, but Multicast transmission distributes its flow bandwidth by depending on the amount of receivers. It consumes a large bandwidth for transmission of the same data between different SSs. The integration of a multicast group member in each SS favorably affects the usage of system bandwidth resources. However, as the number of SSs connected to the BS continuously increases, the best approach is to integrate BS by marking on DL_MAP. Thus, it can deliver the best performance because many SSs receive data from the same multicast sender. Fig. 12 shows that with the stated number of SSs, the scheme without multicast integration clearly expands with an increase in bandwidth usage by multicast group members. Furthermore, the number of members does not influence SS collection. In fact, the SS collection is higher than the BS collection.

Multicasting is used for downlink data transmission in an IEEE 802.16 PMP network, but if we consider a multicast group member with CID integration, the SS will reduce signal message on sending a refresh control signal. For this reason, we have shown the signal cost in Fig. 13 and Fig. 14. The number of SSs will have an obvious effect on SS collection; however, in the traditional approach, the same multicast member sends a control signal to the BS through the SS. Thus, we understand that in the traditional approach, the number of signals depends on the number of multicast group members. If we integrate a flow into an SS and the BS, the number of control signals clearly decreases. This behavior is significantly similar to that exhibited with regard to bandwidth usage. Moreover, as shown in Fig. 14, the number of multicast group members has a significant effect on the traditional approach, but it does not affect SS or BS collection.

These simulation results indicate that the IP and 802.16 MAC layers improve the bandwidth utilization and decrease the signal cost of an IEEE 802.16 PMP network. Thus, these layers can improve data transmission efficiency and reduce control signal overheads.

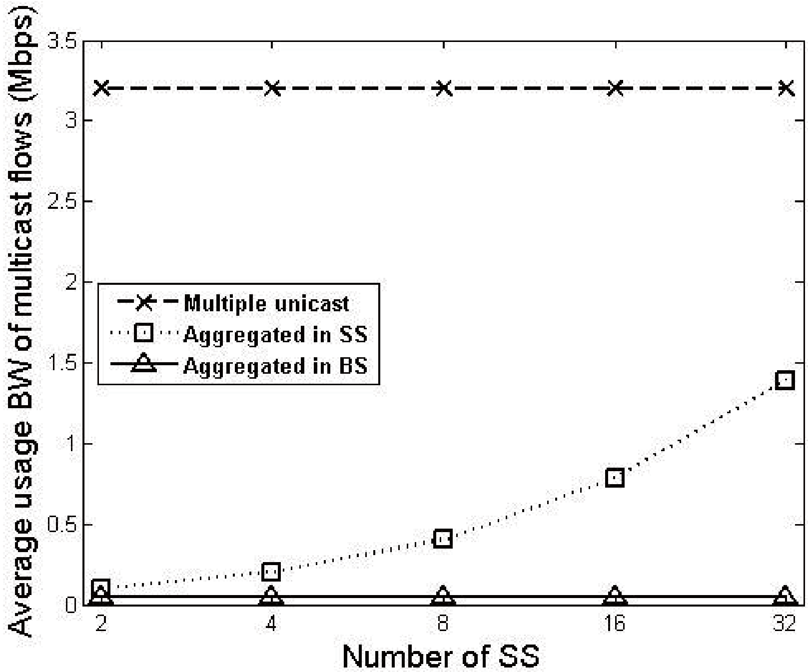

Fig. 11. 802.16 bandwidth utilization (# of SS)

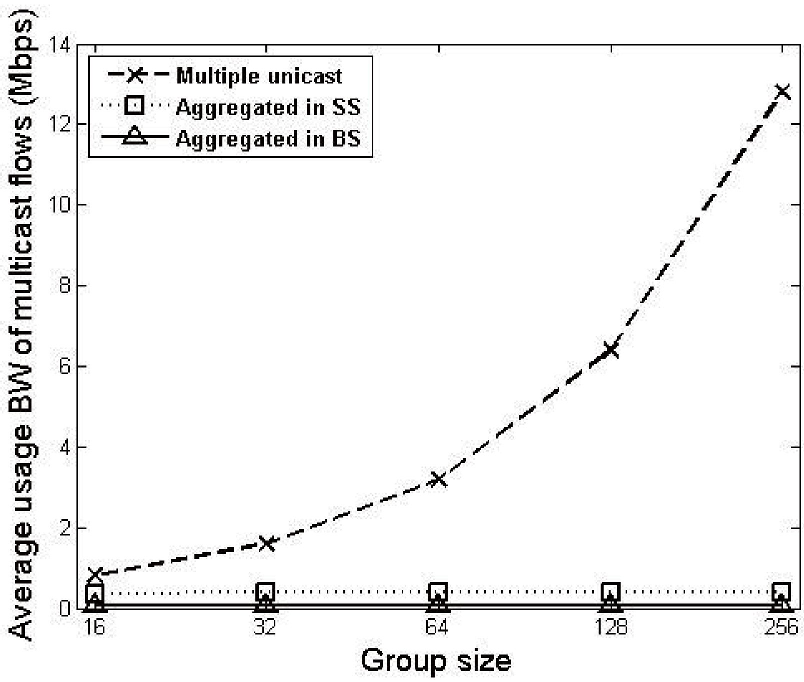

Fig. 12. 802.16 bandwidth utilization
(multicast group size)

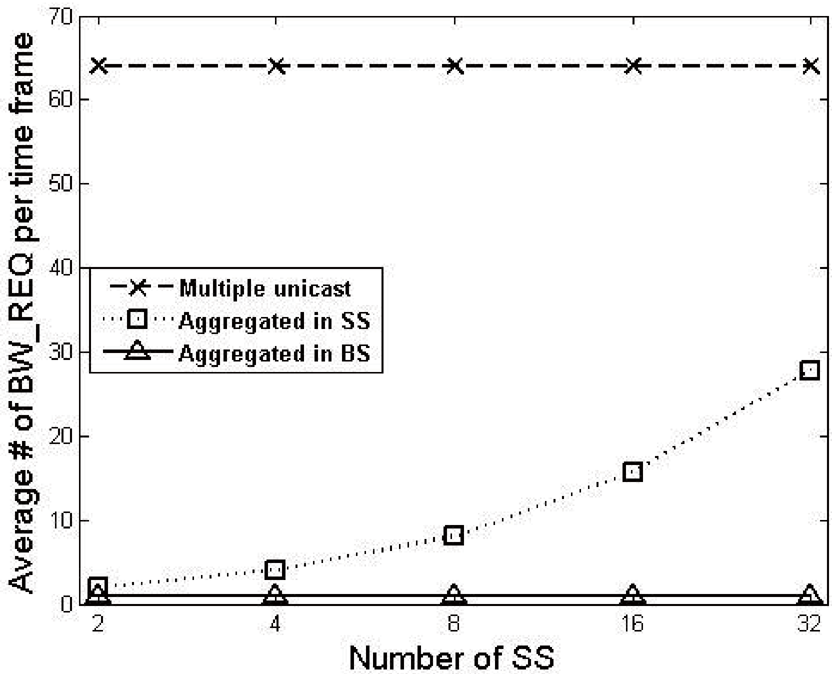

Fig. 13. signal cost (# of SS)

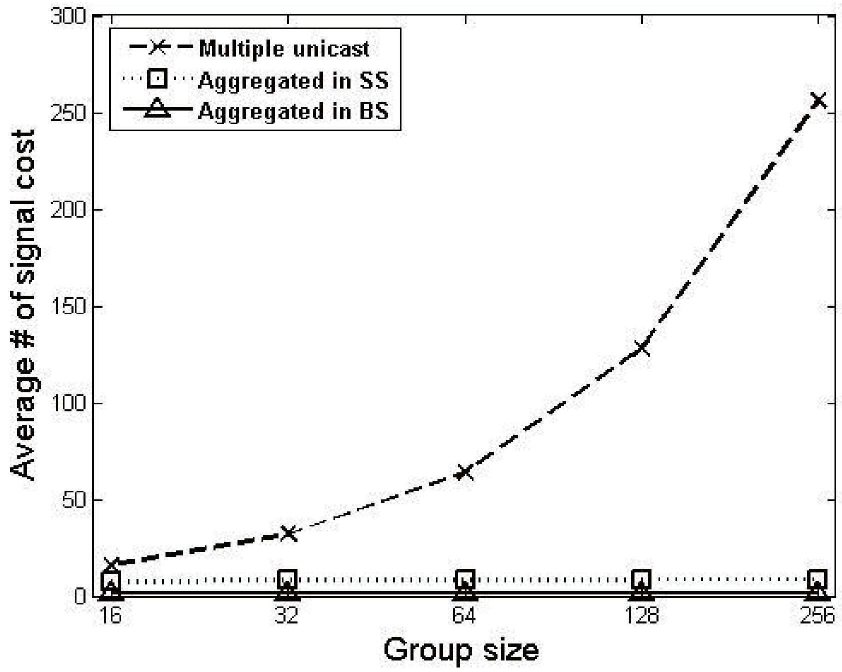

Fig. 14. signal cost (multicast group size)

5 Conclusion

IP Multicast services are gaining in popularity on the Internet, and an IP Multicast scheme improves Internet bandwidth usage. Further, an IEEE 802.16 network enables the deployment of a wide range of wireless networks. For an IEEE 802.16 PMP network and backhaul Internet, the network can integrate IP Multicast and an 802.16 MAC layer. Thus, it simply integrates SSs and the BS with the original approach, which transmits data by flow member to have more efficient effect on 802.16 wireless networks. In addition, we integrate IP Multicast and 802.16 CIDs with the BS and combine the integrated BS with previous wireless network broadcasting approaches in order to improve bandwidth utilization.

Our simulation results reveal that if we obtain more information about L3 traffic in IEEE 802.16 networks, we can integrate the IP and 802.16 MAC layers when transmitting multicast data and thereby efficiently decrease bandwidth usage and signal costs. Thus, the results demonstrate that our proposed scheme delivers good performance.

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