ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

Volume 3, Special Issue 3, March 2014

2014 International Conference on Innovations in Engineering and Technology (ICIET'14)
On 21st & 22nd March Organized by

K.L.N. College of Engineering and Technology, Madurai, Tamil Nadu, India

Priority-Based Resource Allocation Scheme For Scalable Video Multicast In IEEE 802.16j Relay Networks

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Abstract— Recently, Worldwide Interoperability for Microwave Access (WiMAX) also known as IEEE 802.16 has received much attention for supporting broadband wireless access over long distance with high Quality-of-Service (QoS). The introduction of Relay Station (RS) in WiMAX is a key feature of IEEE 802.16j standard and Mobile Multihop Relay (MMR) networks based on the IEEE 802.16j standard are able to extend the coverage area as well as to provide better performance than the mobile WiMAX networks (IEEE 802.16e). However, distributing the available resources among all the users is the most common problem in WiMAX networks and its more complicated in IEEE 802.16j relay networks since, the resources should be allocated to both the Subscriber Stations (SSs), and Relay Stations. This paper, we formulated Greedy Weighted Algorithm (GWA) which calculates the priority and weighted value for every user based on the available bandwidth. The proposed algorithm can cleverly avoid redundant bandwidth allocation issue by using this priority based bandwidth allocation mechanism and thus we achieved high network performance (such as increased network throughput or maximum number of satisfied users).

Keywords— WiMAX (IEEE 802.16), Quality of Service (QoS), Mobile Multihop Relay networks (MMR), Relay Networks (IEEE 802.16j), Mobile WiMAX networks (IEEE 802.16e), Greedy Weighted Algorithm (GWA)

I. INTRODUCTION

Worldwide interoperability for microwave access (WiMAX) is a standard of telecommunication technology called IEEE 802.16. WiMAX is an emerging last-mile technology to provide the guaranteed bandwidth and better coverage to the remote rural or suburban areas [1],

[2]. WiMAX (IEEE 802.16c) was first designed at 10-66 GHz spectrum for Line-of-Sight (LOS) communication. Later versions (IEEE 802.16a, d, e) support Non-Line-of-Sight (NLOS) communication by using the radio bands between 2-11 GHz [3]. The IEEE 802.16 standard supports three different physical layer (PHY) operations such as single carrier, orthogonal frequency-division multiplexing (OFDM), and orthogonal frequency-division multiple access (OFDMA). WiMAX works similar as Wi-Fi (IEEE 802.11) does, but it is more improved and well-organized wireless network. Wi-Fi range is up to some hundred meters with 54 Mbps whereas WiMAX can provide broadband wireless access in range up to 30 miles (50 kms) with maximum data rate of 70 Mbps [4], [5]. Recently IEEE 802.16 has formed a task group named IEEE 802.16j or relay networks to extend the coverage range of IEEE 802.16e/mobile WiMAX standard. The typical IEEE 802.16j relay network components include Base Stations (BSs), Relay Stations (RSs) and Mobile Users (MUs) or Subscriber Stations (SSs). IEEE 802.16j relay networks include multihop communication by placing the relay stations between base station and mobile station. Generally RSs support both the uplink and downlink to forward the data over the wireless medium. If the communication takes place on behalf of relay station then the link between BS and RS is called as *relay zone* and the link between RS to SS will act as *access zone*. The direct link from the BS to SS will act as a *direct zone*. Fig. 1 shows the general structure of WiMAX relay network. Over the last decade, deployment of wireless broadband communication and demand for sharing the multimedia contents over wireless networks has grown

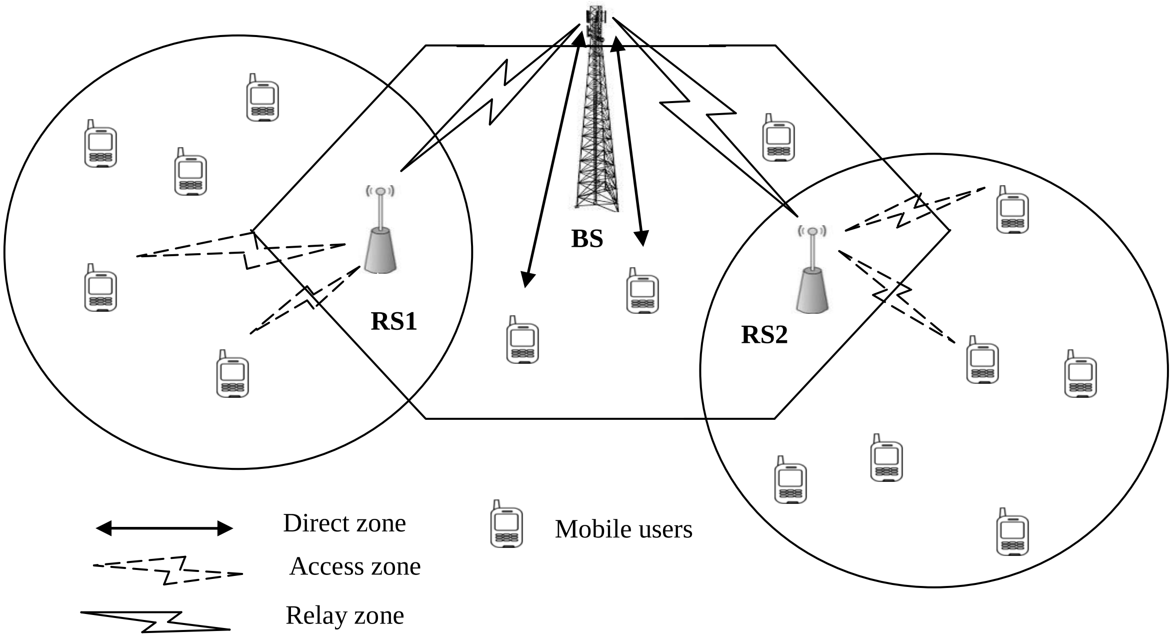

Fig. 1. Structure of WiMAX relay network

rapidly. Multicast technology is a key technology for next generation cellular networks that transmits the same data to multiple users [6]. Video coding technologies have been examined and developed continuously by Joint Video Team (JVT) of ISO/IEC Moving Picture Experts Group (MPEG) and ITU-T Video Coding Experts Group (VCEG) [7]. The recent research is Scalable video coding (SVC), which is the extension of the H.264/AVC standard to improve the video delivery and fairness over the network. SVC splits a video stream into multiple substreams and it has one base layer and one or multiple enhancement layers. Only base layer content is enough to achive basic quality, video resolution and frame rate whereas, enhancement layer contents are required to provide high quality video.

In this paper we thoroughly examined the resource allocation problems of video multicast in WiMAX relay networks and presented a table consulting mechanism to carry out various performance objectives. Resource allocation problems in WiMAX relay networks are most complex as compared to mobile WiMAX because, mobile WiMAX networks only consists of BS and SSs. Otherwise we can say all the SSs are directly connected with BS (single hop) in mobile WiMAX, whereas in WiMAX relay networks the RSs are used to link the SSs with BS. Thus we should allocate the resources not only for the SSs also to the RSs in IEEE 802.16j and this will lead to the bandwidth wastage and impractical, due to its computational complexities. The proposed algorithm overcomes the issues in relay networks by using the table based resource allocation mechanism, also this algorithm achieves maximum number of satisfied users and increased throughput under limited bandwidth. A weighted value for each user is calculated based on the parameters like data rate, bandwidth and number of mobile users. These weighted values are used to find which SS should serve first and to determine the corresponding serving priority.

The remaining part of the paper is organized as follows. Section II involves the works related to the resource allocation schemes in WiMAX systems mainly on video stream multicast. Section III proposes a resource allocation scheme for IEEE 802.16j relay networks. Section IV presents some simulation results of the proposed algorithm. Finally, Section V states the conclusion.

II. Related Work

Scalable video transmissions over WiMAX network have attracted many researchers in recent years. Similar to our work, many studies aim to improve the performance of WiMAX networks [8-15]. In [10], Hong and Kim proposed wireless switched digital video (WSDV) scheme to increase the limited wireless capacity and simultaneously accommodating many users to watch the same channel.

The result of their model improves the spectral efficiency for mobile TV services in WiMAX networks also it can provide an accurate estimate of the amount of bandwidth required for WiMAX TV services. In [11], Haghani et al. explained the challenges in wireless networks while transmitting the video traffic, and discussed some of the WiMAX networks limitations and design considerations, which can significantly impact the video quality. To improve the video quality they have introduced a cross-layer approach which relies on the characteristics of the MPEG frames and the detailed QoS classification features at the WiMAX MAC layer. Huuskoa et al [12] proposed well-organized cross-layer communication method and protocol architecture in order to transmit the control information and to optimize the multimedia transmission over wireless and wired IP networks. Also they have illustrated how the scalable video transmission can be improved by use of the proposed cross-layer approach.

Various researchers have dedicated their efforts towards improving the resource utilization of IEEE 802.16e mobile WiMAX networks. The authors of [13], [14] proposed an uplink and downlink resource allocation schemes for IEEE 802.16e networks respectively. In [13] Huang et al., argued that the scheduling and resource allocation in uplink is complicated as compared to downlink and presented an optimization-based formulation technique. Whereas in [14] Rashid et al., proposed a queue and channel aware scheme as a resource allocation framework to provide quality of service support in the downlink of an IEEE 802.16e mobile WiMAX system. J. She et al. [15] concentrated on bandwidth allocation problem in mobile WiMAX (IEEE 802.16e) networks. They have presented a two-level modulation schemes, in first level they used QPSK and BPSK (lower data modulation code) in order to transmit the base-layer video data whereas higher data modulations, such as 16-QAM and 64-QAM are used in second level to transmit the enhancement layer video contents.

However, these methods cannot produce comparable performance for WiMAX relay networks, because 1) The resources should be allocated for both the BS and RSs in the network, and 2) Interference problems may occur due to RSs during the data multicast.

III. Proposed Model

The proposed model is concentrated on the resource allocation problems in two-hop WiMAX relay networks as similar to the previous approaches [16-18], [20-26]. As shown in Fig. 2, the proposed model consists of one BS, one RS and four SSs. In Fig. 2, a solid line represents the channel quality (CQ) of the link between the BS and RS while dotted line represents the channel quality between RS and SS. DR represents the data rate required by SSs. This model consists of four modulation and coding schemes (BPSK, QPSK, 16-QAM and64-QAM). Assume that the lower channel quality links should use highly reliable modulation schemes. BPSK offers the high reliability among these four schemes (suitable for links with bad channel quality) and 64-QAM is suitable good channel quality links which provides the fastest transmission rate. Assume that every SSs has its own device capabilities and this SSs may request the same video with different quality. The H.264/SVC standard defines many video quality levels for their individual data-rate requirements. Here the proposed system considers six video quality levels 1, 1b, 1.1, 1.2, 1.3, and 2 [21], and this model uses the maximum bit rate as a data rate, 64, 128, 192, 384, 768, and 2,048 kbit/s respectively. These data rates are specified for user convenience only but the proposed resource allocation scheme can also operate under any other data rates. Depending on the device capability the user can select a quality level. For example, when a user requests a video under video quality level 1, the BS should guarantee a 64 kbit/s data rate to that user, and its DR equals 64 kbit/s. In order to provide different data rates, the H.264/SVC splits a video stream into one base layer and multiple enhancement layers. For instance, a user with the requirement of 64 kbit/s can be satisfied by receiving the base layer, whereas a user with

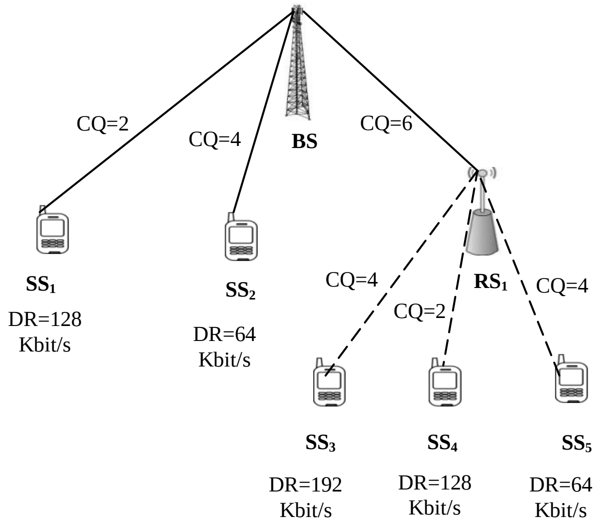

Fig. 2. Example of proposed model

the requirement of 128 kbit/s can be satisfied by receiving the base layer and one enhancement layer. Resource allocation decisions are made for each frame in IEEE 802.16j relay networks. This study concentrated on the downlink multicast problems. The downlink process can be divided into two zones, named as an access zone and a relay zone. The BS transmits the video data to its RSs and SSs in access zone while in relay zone, the RSs further relay the video data to their served SSs. The BS should make a scheduling decision at the beginning of every frame to determine the data transmissions by using an appropriate resource allocation scheme. Shannon-Hartley theorem is used to calculate the bandwidth consumption for every user. This theorem states that,

$$B = C/(\log_2 L) \tag{1}$$

Here C signifies the channel capacity of the link (in bit/s), B represents bandwidth (in Hertz), and L represents the number of signal elements for a modulation scheme. For example, L's value for BPSK, QPSK, 16-QAM, and 64-QAM are 2, 4, 16, and 64, respectively. If SSx,y links to the BS with QPSK has the required data-rate DRx,y is 128 kbit/s, then the bandwidth required to serve the SSx,y would be $128/\ (\log_2 4\ ) = 64\text{k}$ Hertz. Here the selection of an appropriate modulation scheme is based on the channel quality and we divide the channel quality into four subclasses as 1, 2, 4, and 6, the corresponding modulation schemes are BPSK, QPSK, 16-QAM, and 64-QAM. The minimum bandwidth requirement B is calculated as,

$$B_{req} = DR_{x,y}/CQ_x + DR_{x,y}/CQ_{x,y} \tag{2}$$

Where $DR_{x,y}/CQ_x$ signifies the required bandwidth for first hop (from BS to RS) and $DR_{x,y}/CQ_{x,y}$ signifies the required bandwidth for second hop transmission (from RS to SS). For instance, the minimum bandwidth requirement for SS_4 in Fig. 2 is, $B_{req} = DR_4/CQ_3 + DR_4/CQ_{3,2} = 128/6 + 128/2 = 85.33\ kHz.$ When a BS or RS multicasts a video data, group of SSs (within the BS/RS's coverage range) will receive the data concurrently.

TABLE I.SERVING PRIORITY FOR NETWORK THROUGHPUT

User	DR	Bandwidth	Weighted value	Priority
SS_1	128	128/2=64kHz	128/4=2	4
SS_2	64	64/4=16kHz	64/16=4	1
SS_3	192	192/6+192/4=80kHz	192/80=2.4	2
SS_4	128	128/6+128/2= 85.33kHz	128/85.33=1.5	5
SS_5	64	64/6+64/4=26.67kHz	64/26.67=2.4	3

TABLE II. MULTICAST TABLES

(A) FOR SS_2

MCS	DR for BS (kbit/s)	DR for RS (kbit/s)
BPSK (1)	0	0
QPSK (2)	0	0
16-QAM (4)	0 to 64	0
64-QAM (6)	0	0

(B) FOR SS_1

MCS	DR for BS (kbit/s)	DR for RS (kbit/s)
BPSK (1)	0	0
QPSK (2)	0 to 128	0
16-QAM (4)	64	0 to 192
64-QAM (6)	0	0

If the BS/RS multicasts the video data using the modulation scheme corresponding to its CQ, then the video can only be received by the SSs who having the channel quality higher than or equal to the corresponding CQ.

Consider the Fig. 2, If the base station multicasts the video by use of 64-QAM (with CQ=6) then the RS_1 only can receive the video. On the other hand, the BS uses 16-QAM (with CQ=4) then the RS_1 and MS_2 can receive the same video data simultaneously.

A. Proposed Resource Allocation Method

Here we have considered an IEEE 802.16 relay network with a limited amount of resource and proposes an algorithm to increase the network throughput and number of satisfied users. Due to bandwidth limitations all the SSs cannot be satisfied at the same time. It is important to determine that, which set of SSs should avail the bandwidth first and the serving priority for the same SS should be calculated in order to improve the network performance. We developed an algorithm called Greedy Weighted Algorithm (GWA) which decides the set of SSs and serving priority to efficiently use the limited bandwidth. The weighted value W for each SS is defined as the performance gain by using the bandwidth. Proposed GWA algorithm sequentially examines the SSs for bandwidth allocation based on the weighted value W in decreasing order. If one or more SSs have the same weighted value W, then the priority to MS will be in random order.

1) Throughput Maximization Under Limited Resource

To increase the network throughput here we are considering GWA algorithm, by using the weighted value W as throughput gain per bandwidth DR/B, where DR is the data rate required by user and B is the amount of bandwidth to serve the particular SS for both the first hop and the second hop. Consider the model in Fig. 2, its equivalent weighted values for all the SSs and the serving priority has calculated and listed in Table I. Initially all the DR fields in the multicast table is set to be zero. SS_2 has the highest priority and it is analyzed first. In order to satisfy SS_2 the DR field of 16-QAM in multicast table (for BS alone) is modified from 0 to 64 Kbit/s (Table II. A). The next prioritized user is SS_3 with req-uired data rate of 192 Kbit/s. In previous step BS is allocated to 64 Kbit/s but it is not enough to satisfy SS_3, because it required high data rate. So the DR field of 16-QAM is modified from 64 to 192 Kbit/s in BS table. In this case the DR field for RS should be updated because SS_3 has two-hop communication (BS to RS_1 & RS_1 to SS_3) thus DR for RS is modified from 0 to 192 Kbit/s in 16-QAM modulation scheme. GWA further examines SS_5 and it requires only 64 Kbit/s with CQ = 4.

Last bandwidth assignment is well enough to satisfy the SS_5 because the BS and RS both have already assigned more than 64 Kbit/s in 16-QAM field. Next SS_1 is examined, it requires 128 Kbit/s with poor channel quality (CQ=2). Even though BS has equal bandwidth (128 Kbit/s = DR_1) this data rate using 64-QAM cannot be received by SS_1 due to its poor channel quality. In this scenario, the DR field of QPSK in multicast table should be updated as 128 Kbit/s with respect to the requirement of SS_1 (Table II. B). Similar procedure is repeated for the remaining SSs until all SSs requests have been processed. If the available bandwidth is insufficient to satisfy any SS means the proposed GWA simply skips that SS and proceeds to serve the next SS.

2) Increasing Number of Satisfied Users under Limited Resource

Satisfying a user is a major concern for service providers and this part concentrated on increasing the number of satisfied users under the limited resource.

TABLE I.. SERVING PRIORITY FOR SATISFIED USERS

User	$User_x$	Bandwidth	Weighted value ($User_x$/B)	Priority
SS_1	1	128/2=64	1/64=0.015	4
SS_2	1	64/4=16	1/16=0.062	1
SS_3	2	192/6+192/4=80	2/80=0.025	3
SS_4	1	128/6+128/2=85.33	1/85.33=0.011	5
SS_5	1	64/6+64/4=26.67	1/26.67=0.037	2

TABLE II. ALLOCATION STATUS FOR ALL MSS

Priority	User	Residual bandwidth	Allocation status
1	SS_2	80-(64/4)=64	Yes
2	SS_5	64-(64/4)=48	Yes
3	SS_3	48-(128/6+128/4)=-5.33<0	No
4	SS_1	(48+128/6)-(128/4)=5.33	Yes
5	SS_4	(5.33+128/4)-(128/2)<0	No

TABLE III. FINAL MULTICASTING TABLE FOR SATISFIED USERS

MCS	DR for BS (kbit/s)	DR for RS (kbit/s)
BPSK(1)	0	0
QPSK(2)	128	0
16-QAM(4)	64	192
64-QAM(6)	0	0

(a)

(b)

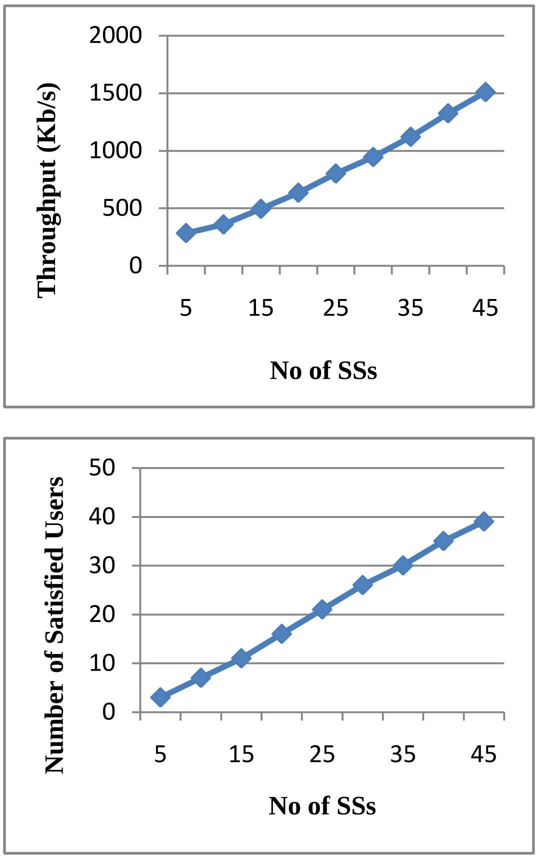

Fig . 3 (a) Network throughput for different number of MSs and (b) Number of satisfied users for different number of MSs

In this case we define that, a user is a satisfied user when the data-rate requirements are fully achieved. This section also using a weighted value but it is different from the previous section. Here we define the weighted value W as, $W_x = user_x / B_x$. Where $user_x$ represents the users count that how many users getting satisfied simultaneously. For example in Fig. 2, $user_3 = 2$, because while satisfying SS_3, SS_5 also got satisfied due to its equal channel condition. Whereas, $user_2 = 1$ because while serving SS_2, its neighbors SS_1 and RS_1 are having different channel quality and thus cannot be satisfied concurrently. Table III lists the $user_x$, B, W and the serving priority for all the SSs.

Assume that the limited bandwidth $B_{limit} = 80\ k\ Hertz$. The proposed algorithm prioritized all the SSs based on the W as shown in Table IV. As per the priority order SS_2 is examined first, the initial bandwidth (80 k Hertz) is sufficient to support the DR 64 kbit/s from the BS to SS_3 ($80 - (64/4) = 64\ \text{kHz} \geq 0$). Hence, the DR fields of 16-QAM for BS is first modified as 64 kbit/s. Next SS_5 is taken and to satisfy this user we need 64 kbit/s for RS. We additionally need only $64/4 = 16kHz$ bandwidth to support SS_5 $(64 - (64/4) = 48\ kHz \geq 0)$. While SS_3 is examined it requires 192 kbit/s, but already the BS and RS has assigned 64 kbit/s. Thus we need extra 128kbit/s to support the SS_3 with channel quality of 6 for first-hop transmission and 128 kbit/s with CQ of 4 (i.e., $(48 - ((128/6) + (128/4)) = -5.33 < 0)$. So we cannot satisfy the SS_3 with this limited bandwidth (B_{limit} = 80KHz). The proposed GWA algorithm consecutively

(a)

(b)

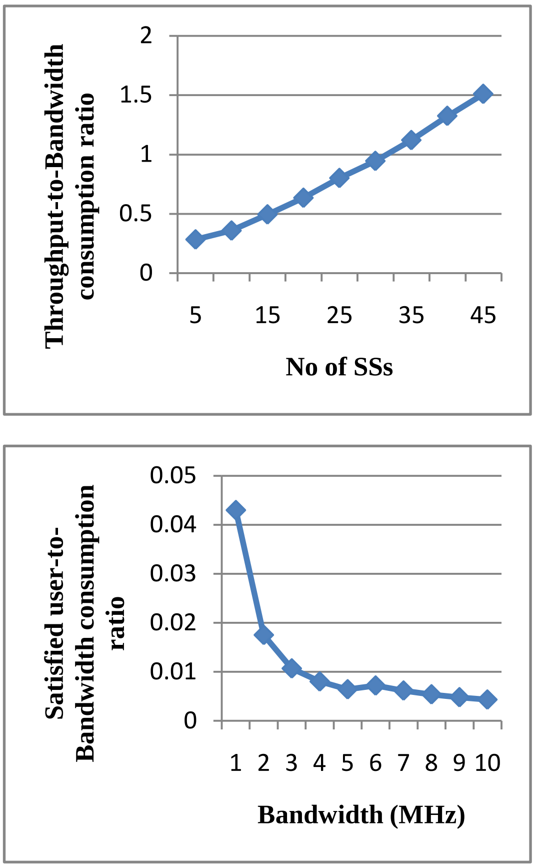

Fig. 4 (a) Network throughput-to-bandwidth consumption ratio and Users-to-bandwidth consumption ratio

examines SS_1 and SS_4 in similar manner. While serving SS_1 the previous bandwidth allocation for BS is unavailable for SS_1 because, it has poor channel quality. To avoid bandwidth wastage the proposed GWA reclaims the extra bandwidth and select the suitable bandwidth for all the users. Thus bandwidth for SS_1 is reclaimed (128 kbit/s with CQ=6) and multicast table is as $(i.e., (48 + (128/6)))$. After all the process, the multicast tables are determined and final multicast table for BS and RS is shown in Table V.

IV. Results And Performance Analysis

This part presents the simulation results of the proposed GWA algorithm. We used NS2 (Network Simulator 2) for simulation analysis and the proposed WiMAX relay network consists of five RSs which all are controlled by single BS. Initially the locations of the RSs and MSs are randomly selected. Based on these locations the channel quality of both access links (BS to MSs or RSs to SSs) and relay links (BS to RSs) are set as randomized manner (1, 2, 4, or 6) and corresponding modulation schemes assigned to these links. The uplink and downlink bandwidth selected for simulation is 5 Mb. The channel quality is purely based on the distance between the links from BS/RS to RS/SS. If the distance is less, then the channel quality will be high and vice versa. The entire simulation work is carried out by using Destination Sequenced Distance Vector Protocol (DSDV) ad-hoc routing protocol. Fig. 3(a) shows the graph for network throughput for different users and Fig.3 (b) plot the graph for number of satisfied users among selected users.

TABLE III. THE PARAMETERS USED FOR SIMULATION

Number of BSs	1
Number of RSs	5
Number of MSs	45
Packet size	1000 bytes
Interval	0.1 ms
Mobility model	Random way point model
Mobility rate	20m
Modulation schemes	BPSK,QPSK,16-QAM,64-QAM
Data rates	64 kbit/s, 128 kbit/s, 192 kbit/s

This is calculated by using PDR (Packet Deliver Ratio) and number of users joined to BS. Figs. 4a and 4b shows the graph between throughput-to-bandwidth ratio for different users and number of users-to-bandwidth ratio as a function of bandwidth respectively. While increasing the amount of bandwidth, the number of user-to-bandwidth ratio decreases and the number of satisfied users increases. The parameters are listed in Table VI.

V. CONCLUSION

In this paper we concentrated on the resource allocation problem in WiMAX relay networks. For this purpose, we have formulated a network with single hop and two hop communications by use of relay stations. We have constructed a table consulting mechanism for an efficient resource allocation in WiMAX relay networks. By using weighted value and priority the proposed GWA algorithm constructs multicast tables for BS and RSs. Through simulation results we can conclude that the proposed GWA algorithm achieves increased throughput and maximum number of satisfied users while increasing the amount of users.

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