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BGWA Based Resource Allocation Scheme in WiMAX Relay Networks

[1]Kavitha, P. and [2]Dr. Umarani, R.

[1]*Bharathiyar Arts & Science College for Women, Department of Computer Science, Kavitha .P, Box.3030. Salem. India.*
[2]*Sri Sarada College for Women, Department of Computer Science, Dr. Umarani .R, Box.3030. Salem. India.*

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ABSTRACT

Background: BGWA Based Resource Allocation Scheme in WiMAX Relay Networks. **Objective:** WiMAX is an emerging technology that delivers broadband wireless access, wide service coverage and high data rate. The bandwidth management in WiMAX has become a significant issue that requires efficiently assigning the bandwidth among challenging users according to their services and due to its robust wireless channel. When the accessible bandwidth is inadequate, the bandwidth allocation problems are occurring. To maximize the number of user's satisfaction and throughput this paper proposes an efficient resource allocation scheme called Bounded Greedy Weighted Algorithm (BGWA) for bandwidth allocation. The proposed scheme supports unicast mechanism which can be applied to any kind of wireless networks. This method perceptively avoids redundant bandwidth and provide high performance in worst case performance. The performance of the proposed method is estimated by simulation. The simulation results show that the proposed method can allocate resources perfectly and provide better performance than existing method in terms of network throughput and bandwidth utilization. **Results:** The performance evaluation of the proposed BGWA algorithm is discussed in this section. The proposed algorithm is compared with the optimal algorithm. To solve the 0/1 knapsack problem such as maximizing network throughput and maximizing the number of satisfied users, the optimal algorithm applies the brute force method. To compute the optimal solution to these problems, the optimal algorithm computes all possible combinations of serving SSs. **Conclusion:** This paper evaluates the bandwidth allocation issue of scalable video unicast transmission in WiMAX relay networks. A bounded greedy weighted algorithm is developed to solve the problems such as maximizing the network throughput and maximizing the number of user satisfaction. Based on the weighted value, the proposed BGWA method makes the local optimal choice instead of computing all possible choices to find a globally optimal solution. This paper theoretically analyzes the worst case performance of BGWA. The estimated results show that the proposed BGWA algorithm provides better network throughput for different number of subscriber station. In future enhancement, the resources will register and then allowed it for route discovery using Call Admission Control (CAC).

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INTRODUCTION

THE Worldwide Interoperability for Microwave Access (WiMAX) is an efficient technology, which offers broadband wireless access and provide high data rate, strong Quality of Service (QoS) and wide service coverage (Esmailpour, A. and N. Nasser, 2011). The distinctive IEEE 802.16j network components comprise Subscriber Station (SS) or Mobile Station (MS), Base Station (BS) and Relay Station (RS). It is fully compatible with IEEE 802.16e standard by incorporating relay technology. The base station allocates resource to the subscriber station in both uplink and downlink directions. It is the essential entity which controls the channel usage within the coverage of each WiMAX cell. Before the communication is established, each SS transfers its burst profile with the related BS. The BSs and RSs can provide high data rate and the end to end channel qualities can be improved when RSs are organized at suitable locations between the BSs and SSs. Because of upgrading data rate, IEEE 802.16j provides a higher throughput than IEEE 802.16e systems. Figure 1 shows that the architecture of WiMAX IEEE 802.16j.

IEEE 802.16j provides real time video multicast services such as live video streaming, online gaming and mobile IPTV (Nguyen, H.D., 2011). While ensuring the Quality of user Experience (QoE), the BS should assign

Corresponding Author: Kavitha, P., Bharathiyar Arts & Science College for Women, Department of Computer Science, Kavitha. P, Box.3030. Salem. India.
Ph: 04282 – 230799, E-mail: kavithaphd2013@yahoo.com.

bandwidth proficiently to support bandwidth hungry services. In IEEE 802.16j the BS allocate bandwidth to both SS and RS. Hence, the bandwidth allocation challenge is more than in IEEE 802.16e networks.

Various bandwidth allocation approaches have been proposed early for video services in 802.16e networks. In some approaches, the bandwidth is assigned by common technology of scalable video coding specified in H.264/SVC standard. When transmitting the whole video stream, the flexibility of SVC efficiently preserves bandwidth while providing satisfactory video quality.

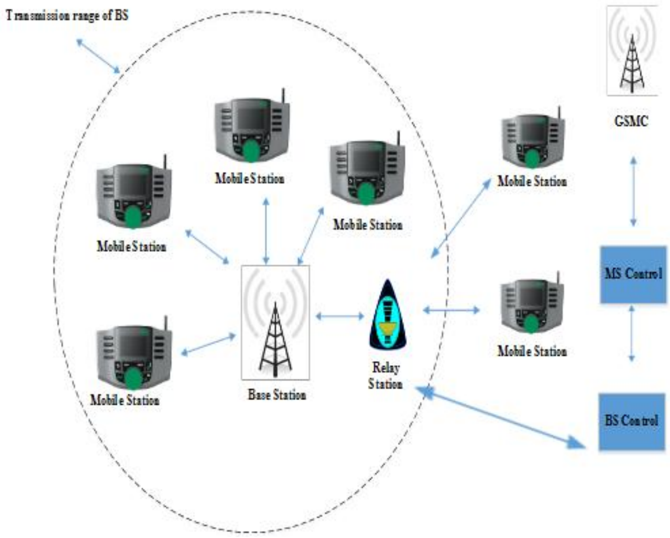

Fig. 1: WiMAX IEEE 802.16j Architecture.

The IEEE 802.16e network approach cannot be directly applied to IEEE 802.16j to achieve equivalent high performance. Because the 802.16e network bandwidth allocation doesn't consider multihop relay issues. The allocation of bandwidth will become more complex, when the relay issues are considered. Existing bandwidth allocation schemes allocate bandwidth inefficiently for real time video services without considering the SVC.

This paper proposes an efficient bandwidth allocation algorithm to maximize the network throughput and number of user's satisfaction. By using a Bounded Greedy Weighted Algorithm (BGWA) the node is located. After that the traffic rate is estimated by using Active Queue Management (AQM) algorithm. If the traffic load is high once again, it will estimate the traffic. Otherwise the Channel State Information (CSI) is estimated. Whenever the base station requests the CSI information, the Report Request (REP-REQ) message is forward to the MS. The CSI has to be acquired in order to decide which routing path has the best characteristics. With the help of that results the data processing and analysis should be done.

The rest of the paper is organized as follows. Section II presents a description about the previous research which is relevant to resource allocation schemes. Section III involves the detailed description about the proposed method. Section IV presents the simulation results of the proposed system. This paper concludes in Section V.

Related Work:

Jain, et al proposed a traffic load and interference based bandwidth allocation scheme (TLIBA) for wireless mesh network. The throughput and delay are improved for assigned bandwidth by proper utilization. Based on traffic load and interference the bandwidth is allocated. After that by using the least routing metric value a suitable path is selected (Jain, S., *et al.*, 2013). *Hwang, et al* proposed an adaptive downlink bandwidth allocation method (DBAM) to maximize the throughput of broadband WiMAX networks. Two adaptive resource adjustment schemes with SVC (Scalable Video Coding) technology in DBAM were proposed based on the traffic throughput and amount of traffic in SVC layers (Hwang, I.S., *et al.*, 2011). For layer encoded IPTV multicast service over WiMAX networks *Kuo, et al* presented the utility based resource allocation problem. This work is proposed to maximize the total utility and the system resource utilization. It supports both multicast and unicast (Kuo, W.H., *et al.*, 2011).

New, et al proposed a study on the bandwidth request for real time polling services (New, W., *et al.*, 2013). *Sheu, et al* presented a resource allocation scheme to support scalable video multicast for WiMAX relay networks. A Bounded Greedy Weighted Algorithm was proposed to maintain the high performance and improve its worst case performance (Sheu, J.P., *et al.*, 2013). *Mowafi, et al* proposed a WiMAX Dual Cognitive Radio

Scheme (WDCRS) for bandwidth allocation in WiMAX systems. To achieve high bandwidth utilization and to increase the total throughput, the proposed method used cognitive radio (Mowafi, M.Y., *et al.*, 2012).

Kumar, et al presented a user bandwidth allocation mechanism, namely Differentiated Bandwidth Allocation Mechanism. WiMAX users were divided into high priority, regular users and low priority users. Based on the priority of the users, bandwidth was allocated to these service class (Kumar, N., *et al.*, 2011). *Al-Mistarihi, et al* proposed an effective bandwidth management system called WiMAX Dynamic Channel Allocation Scheme (WDCAS). To increase the bandwidth consumption, a cognitive radio for dynamic channel allocation was proposed. Based on the maximum entropy principle, a queuing model was proposed (Al-Mistarihi, M.F., *et al.*, 2012). *Jin and Li* proposed a novel cognitive WiMAX architecture with Femto cells. The users and base station were furnished with Cognitive Radio and efficiently alters channel, power, and other resources to accommodate the whole network ecosystems (Jin, J. and B. Li, 2010).

Malik and Zafar proposed an algorithm to maximize the total throughput while maintaining the slot probability among the users. An updated downlink resource management framework was proposed which consists of a DRA module and a CAC module. Aggregate resource allocator and four class schedules were proposed for the DRA module (Malik, G. and F. Zafar, 2013). *Gupta et al* proposed an Efficient Bandwidth Management for dynamic bandwidth allocation algorithm for WiMAX. When the allocated bandwidth is not sufficient to transfer the data, the bandwidth was increased in the upcoming frames. If the allocated bandwidth is more, the bandwidth was decreased in the upcoming frames. The bandwidth is maintained efficiently, hence EBM increases the throughput of real time traffic (Gupta, A. and B.R. Chandavarkar, 2012).

In wireless broadband networks, bandwidth management is essential, due to robust channel. While Subscriber Station are continuously entering and leaving the network, an efficient admission control is essential to monitor the traffics and manages the bandwidth. To manage bandwidth through call admission control for mobile WiMAX, the bandwidth partition approach was proposed (Shu'aibu, D., *et al.*, 2010). Controlling of traffic in large scale network is very important. In guaranteeing the Quality of Service (QoS) requirements for each class of traffic, *Ghazal, et al* proposed a traffic police based on a token bucket concept to decrease the congestion and by consequence. According to the traffic characteristics, token bucket parameters are adjusted for each traffic class individually (Ghazal, S., *et al.*, 2012). *Misra, et al* proposed a novel algorithm for computing bandwidth guaranteed paths for traffic engineering in WiMAX IEEE 802.16 standard using the mesh topology (Misra, S., *et al.*, 2013). *Verma and Garg* gave the overview about the WiMAX standard and the performance of a transmitter and a receiver (Verma, R. and P. Garg, 2013).

Nasser, et al proposed a Utility Optimized QoS scheme for mobile WiMAX. By maximizing bandwidth utilization and minimizing the rejection of both new and handover calls, this scheme maintains a high level of QoS (Nasser, N., *et al.*, 2011). *Karimi, et al* proposed a two level scheduling mechanism in MAC layer of base station for PMP mode of WiMAX networks. This algorithm considers unicast and multicast downlink traffic, including rtps, nrtps and BE. Scheduling algorithms such as WRR and FCFS was proposed in the first level to schedule the connections. Based on aging method, PQ algorithm was used to manage and schedule the packets in the second level (Karimi, R., *et al.*, 2012). On WiMAX networks an important problem is how to provide an assured quality of service for applications. *Jafari Meybodi* described how the packet scheduling problem is modeled as an application for reinforcement learning (Jafari, S.M. and M. Meybodi, 2011).

Resource Allocation Scheme in IEEE 802.16j:

In WiMAX forum, the traffic is divided into unsolicited grand service, real time polling service, non-real time polling service, extended real time polling service and best effort. These traffics have multiple QoS and from random locations, it enters the network in the Poisson process in the coverage area of networking. An efficient and proper method is needed on how these traffics can be acknowledged into the network. According to that, the available bandwidth can be accomplished efficiently. The proposed method is mainly designed for data unicast in IEEE 802.16j networks. With multiple performance objectives the proposed system will allocate bandwidth in a dynamic manner.

If a node wants to transmit a packet to another node, the source node sends route request to all nodes at the wireless sensor range. Based on route discover and route maintenance, the source node sends the request. The target and source is identified by Route Request (RREQ) packet.

BGWA Algorithm:

To improve the performance of resource allocation in a worst case scenario, a modified GWA is proposed to keep high performance in average cases. A Bounded GWA (BGWA) for bandwidth allocation in IEEE 802.16j networks is developed. Let us initializes two sets U_1 *and* U_2 be the solutions of unicast tables. GWA is executed to produce a set of unicast table, and stores this set into U_1. After that the SS should be removed, which can be satisfied using U_1. To create another set of unicast tables, GWA is again executed for the remainder SS and stores this set in U_2. The final solution set $U^*$is determined as U_1 *or* U_2 which produces

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higher profit. According to the unicast tables in U^* the BS allocates bandwidth. To generate two possible sets of unicast tables GWA is executed two times by BGWA. After that it simply selects the better set as the solution.

[1] Algorithm 1: BGWA for bandwidth allocation in IEEE 802.16j

Input: $Ch_{RS} = \{Ch_0, Ch_1, \dots \dots . Ch_U\}$
$Ch_{SS} = \{Ch_{0,1}, \dots \dots . Ch_{u,Nu}\}$
$A = \{A_{0,1}, \dots \dots . , A_{u,Nu}\}$
$Y = \{Y_{0,1}, \dots \dots \dots Y_{u,Nu}\}$
Step 1: U_1 *and* U_2 *be the solution of unicast tables*
Step 2: $GWA(Ch_{RS}, Ch_{SS}, A, Y)$ *is calculated and it is stored to* U_1
Step 3: $Ch_{RS}', Ch_{SS}', A', Y'$ *are attained by removing the SS*
Step 4: $GWA(Ch_{RS}', Ch_{SS}', A', Y')$ *is calculated and it is stored to* U_2
Step 5: U_1 *or* U_2 *whichever results in the higher profits is stored to* U^*
Step 6: Bandwidth is allocated according to U^*

GWA Algorithm:

The GWA is calculated according to the following algorithm 2. The data rate obligation of SS is represented by A. Ch represents the channel quality of the link between the BS and RS. Let us consider temporary variable B_r be a current residual bandwidth. All A fields of the unicast table are initialized as zero and B_r is initialized as B_l. Based on the weighted values of the SS, the proposed method sorts all SS in descending order.

The $SS_{m,n}$ hop count is considered as $hop_{u,n}$. The $SS_{u,n}$'s x^{th} hop bandwidth consumption is defined as $D_{u,n}^{x-hop}$. GWA sets $D_{u,n}^{x-hop}$, $\forall x$ as zero and then compute $D_{u,n}^{x-hop}$ in each hop by consulting with the current multicast tables. To represent Ch_u and UT_0 , CQ and UT is defined for the first hop. To record the total data rate related with the modulation schemes, GWA employs a temporary variable A_T^{x-hop}, to calculate $D_{u,n}^{x-hop}$. No extra bandwidth allocation is needed for $SS_{u,n}$ in the x^{th} hop, if $A_{u,n}$ is less than or equal to A_T^{x-hop}. Extra bandwidth allocation should be maintained in UT, if $A_{u,n}$ is greater than A_T^{x-hop}. Some bandwidth is recoverable, if the present UT already supports any data rates using the other modulation schemes that are less reliable than $modulation[Ch]$. The recoverable bandwidth is calculated by checking each A filed corresponding to a modulations scheme less dependable than $modulation\ [Ch]$. The less reliable $modulation\ [Ch]$ existing data rates can also be fulfilled by $A_{u,n}$. In temporary variable $D_{recover}^{x-hop}$, the total recoverable bandwidth is recorded with respect to redundant data rates. After the bandwidth is calculated, the current residual bandwidth D_r is calculated to check whether it is adequate to support $(D_{u,n}^{1-hop} - D_{recover}^{1-hop}) + (D_{u,n}^{2-hop} - D_{recover}^{2-hop})$. If certainly, the data rate necessities of $SS_{u,n}$ are reflected in the corresponding unicast tables. If $A_{u,n}$ is greater than A_T^{x-hop}, UT is modified by summing $(A_{u,n} - A_{recover}^{x-hop})$ into its A field of Ch. To recover bandwidth for future use, GWT deducts the redundant data rates from the present UT. The total time complexity of sorting in GWA is $O(NlogN)$. For BGWA, the total time complexity is $O(2NlogN) = O(NlogN)$. Thus BGWA method provides better resource allocation than the GWA.

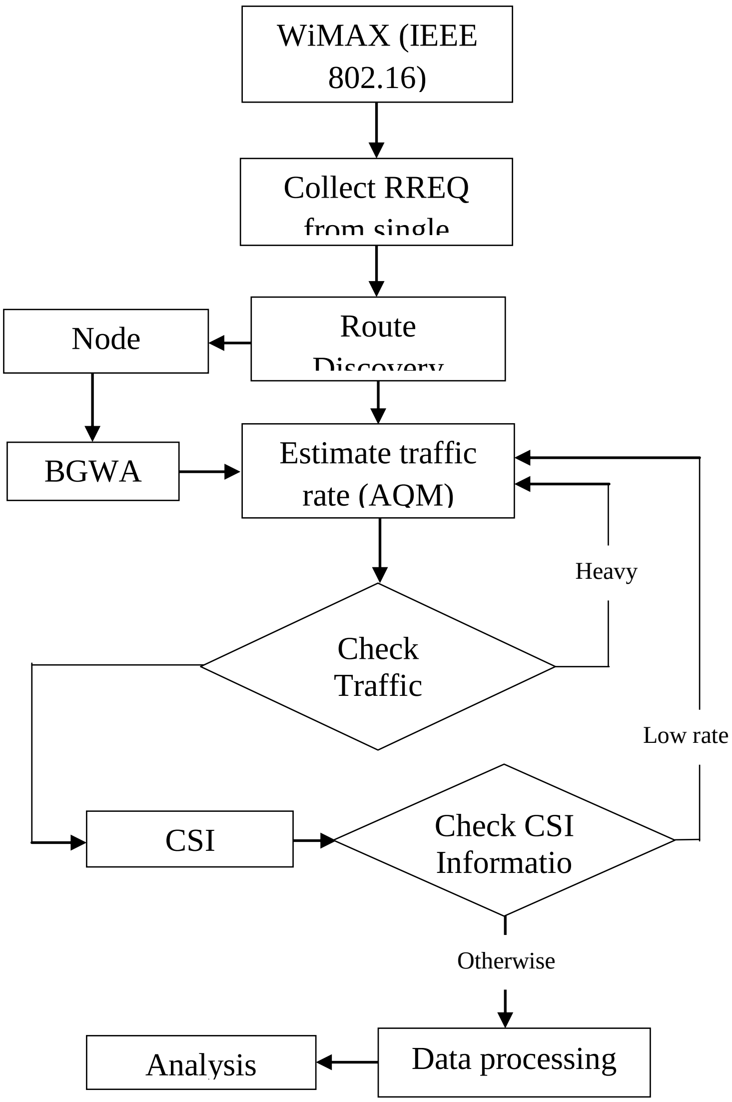

Fig. 1: Flow Diagram of Resource allocation scheme.

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[2] Algorithm 2: GWA for bandwidth allocation in IEEE 802.16j

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Input: $\{Ch_0, Ch_1, \ldots \ldots . Ch_U\}$
$\{Ch_{0,1}, \ldots \ldots . Ch_{u,Nu}\}$
$\{A_{0,1}, \ldots \ldots , A_{u,Nu}\}$
$\{Y_{0,1}, \ldots \ldots \ldots Y_{u,Nu}\}$
$D_r \leftarrow D_L$
for $u = 0$ *to* U
$UT_u \leftarrow \emptyset$
end for
sort SS *into monotonously descending order by weighted values* $Y_{u,n}$
for each $SS_{u,n}$ *taken in the sorting order*
for $x = 1$ *to* $hop_{u,n}$
$D_{u,n}^{1-hop} \leftarrow 0$
for $x = 1$ *to* $hop_{u,n}$
If $x = 1$
Let Ch *and* UT *represent* ch_u *and* UT_0

else if $x = 2$
Let Ch *and* UT *represent* $ch_{u,n}$ *and* UT_u
end if
A_T^{x-hop} $\leftarrow$*total* A *in* UT *using modulation schemes no less reliable than* $modulation[Ch]$
if $A_{u,n} \leq A_T^{i-hop}$
$D_{u,n}^{x-hop} = 0$
else if $A_{u,n} > A_T^{x-hop}$
$D_{u,n}^{x-hop} = (A_{u,n} - A_T^{x-hop})/Ch$
for *each* A *in* UT *using a modulation scheme less reliable than* $modulation[ch]$ *in order from BPSK to 64-QAM*
if *some data rate is redundant due to the support of* $A_{u,n}$ *using* $modulation[ch]$
$D_{recover}^{x-hop} \leftarrow D_{recover}^{x-hop} + the\ recoverable$ *bandwidth if deducting the redundant data rate from* UT
end if
end for
end if
end for
If $D_r \geq (D_{u,n}^{1-hop} \leftarrow D_{recover}^{1-hop}) + (D_{u,n}^{2-hop} \leftarrow D_{recover}^{2-hop})$
for $x = 1$ *to* $hop_{u,n}$
if $x = 1$
Let Ch *and* UT *represent* ch_u *and* UT_0
else if $x = 2$
Let Ch *and* UT *represent* $ch_{u,n}$ *and* UT_u
end if
if $A_{u,n} > A_T^{x-hop}$
Add $(A_{u,n} - A_T^{x-hop})$ *into A field of* Ch *in* UT
for *each* A *in* UT *using a* $modulation[Ch]$ *in the order from BPSK to 64-QAM*
if *some data rate is redundant due to the support of* $A_{u,n}$*using* $modulation[Ch]$ *deduct the redundant data rate from* UT
end if
end for
end if
end for
$D_r \leftarrow D_r - [(D_{u,n}^{1-hop} - D_{recover}^{1-hop}) + (D_{u,n}^{2-hop} - D_{recover}^{2-hop})]$
if $D_r = 0$
break
end if
end if
end if
end for
Allocate bandwidth according to $\{UT_0, UT_1, \ldots .UT_U\}$

After the bandwidth is allocated, the traffic is estimated with the basis of Active Queue Management (AQM) algorithm to overcome the congestion problem. If the traffic load is high, once again, it estimates the traffic rate. Otherwise, Channel State Information is estimated. It is used to calculate the channel properties of a communication link and how the signal propagates from the transmitter to the receiver. If the channel information is at the lowest rate, once again, it will estimate the traffic rate. Otherwise the data processing is done for further analysis.

Result Analysis:

The performance evaluation of the proposed BGWA algorithm is discussed in this section. The proposed algorithm is compared with the optimal algorithm. To solve the 0/1 knapsack problem such as maximizing network throughput and maximizing the number of satisfied users, the optimal algorithm applies the brute force method. To compute the optimal solution to these problems, the optimal algorithm computes all possible combinations of serving SSs.

Figure 2 shows that the comparison graph of network throughput for different amount of bandwidth for the optimal and BGWA algorithm. When the amount of bandwidth increases, the network throughput also increases and the curves of BGWA are much higher than the optimal algorithm.

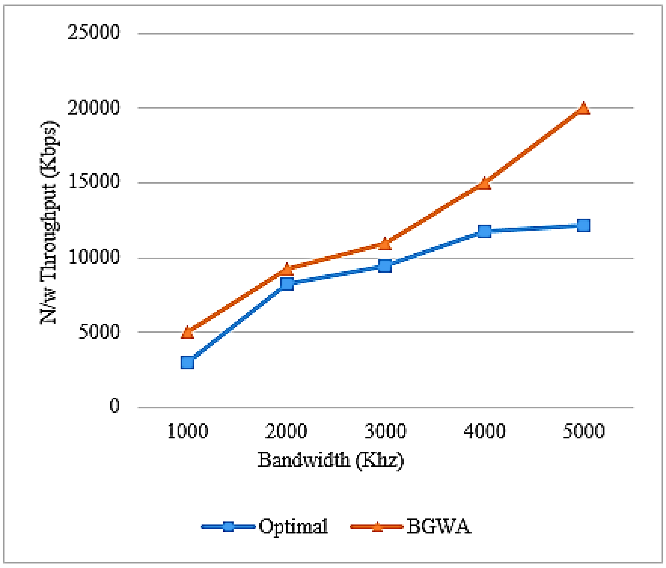

Fig. 2: Network throughput for different amount of bandwidth.

Figure 3 shows that the comparison graph of network throughput with bandwidth consumption for different amount of bandwidth. When the bandwidth is inadequate to satisfy all the SSs, BGWA first allocates the bandwidth to SSs with higher ratios of throughput to bandwidth consumption. Hence the curves of BGWA are higher than the optimal method.

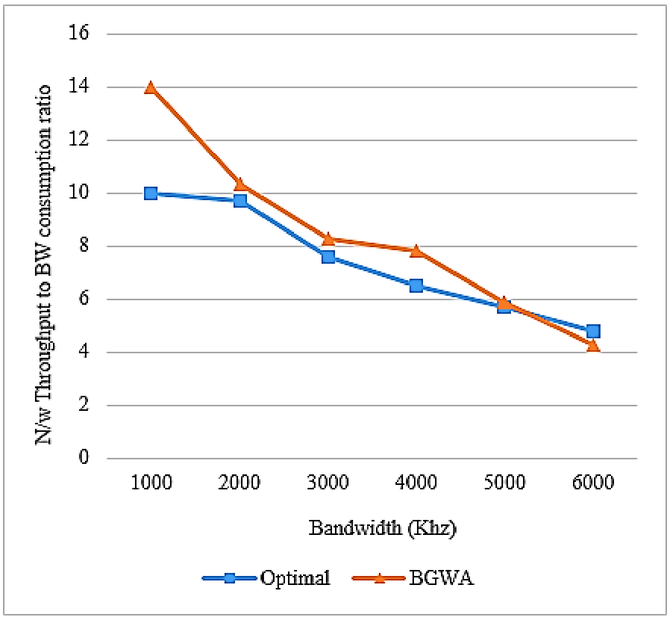

Fig. 3: Network throughput to bandwidth consumption for different amount of bandwidth.

Figure 4 shows that the performance comparison of BGWA and optimal algorithm for network throughput as a function of the number of subscriber station. BGWA provides a higher throughput than optimal algorithm for the different number of subscriber stations.

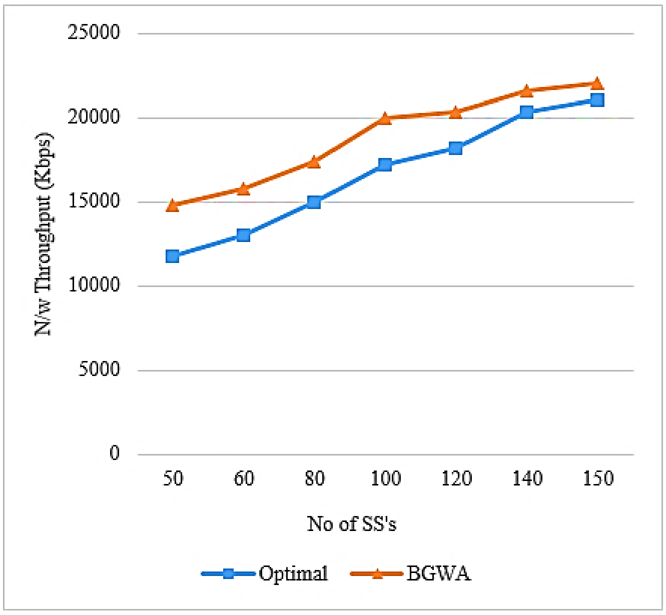

Fig. 4: Network throughput for different number of SSs.

The ratio of network throughput to bandwidth consumption as a function of the number of SSs for BGWA and optimal method in shown in the figure 5. BGWA observes the SSs affords to their weighted values defined as network throughput per bandwidth unit. BGWA provide better performance than the existing method.

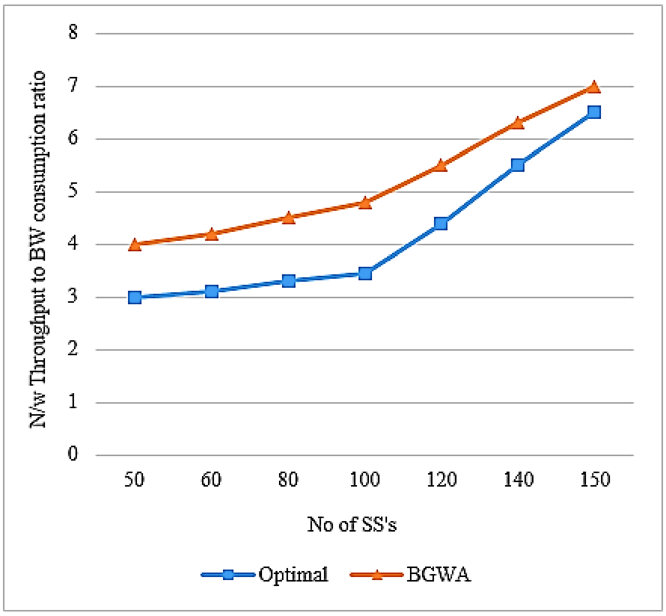

Fig. 5: Network throughput-to-bandwidth consumption ratio for different number of SSs.

Conclusion and Future Work:

This paper evaluates the bandwidth allocation issue of scalable video unicast transmission in WiMAX relay networks. A bounded greedy weighted algorithm is developed to solve the problems such as maximizing the network throughput and maximizing the number of user satisfaction. Based on the weighted value, the proposed BGWA method makes the local optimal choice instead of computing all possible choices to find a globally optimal solution. This paper theoretically analyzes the worst case performance of BGWA. The estimated results show that the proposed BGWA algorithm provides better network throughput for different number of subscriber station. In future enhancement, the resources will register and then allowed it for route discovery using Call Admission Control (CAC).

Australian Journal of Basic and Applied Sciences, 8(9) June 2014, Pages: 78-86

REFERENCES

Al-Mistarihi, M.F., *et al.*, 2012. An optimum scheme for WiMAX bandwidth management using Dynamic Channel Allocation, in MIPRO, 2012 Proceedings of the 35th International Convention, pp: 538-541.

Esmailpour, A. and N. Nasser, 2011. A Novel Scheme for Packet Scheduling and Bandwidth Allocation in WiMAX Networks, in Communications (ICC), 2011 IEEE International Conference on, pp: 1-5.

Ghazal, S., *et al.*, 2012. Traffic management based on token bucket mechanism for WiMAX networks, Cluster Computing, 15: 391-400.

Gupta, A. and B.R. Chandavarkar, 2012. An Efficient Bandwidth Management algorithm for WiMAX (IEEE 802.16) wireless network: EBM allocation algorithm, in Industrial and Information Systems (ICIIS), 2012 7th IEEE International Conference on, pp: 1-5.

Hwang, I.S., *et al.*, 2011. Maximizing downlink bandwidth allocation method based on SVC in Mobile WiMAX networks for generic broadband services, CN, pp: 1-9.

Jafari, S.M. and M. Meybodi, 2011. Bandwidth Allocation in WiMAX Networks Using Reinforcement Learning, World Applied Sciences Journal, 15: 525-531.

Jain, S., *et al.*, 2013. Bandwidth Allocation Based on Traffic Load and Interference in IEEE 802.16 Mesh Networks, Journal of Engineering.

Jin, J. and B. Li, 2010. Cooperative resource management in cognitive WiMAX with femto cells, in INFOCOM, 2010 Proceedings IEEE, pp: 1-9.

Karimi, R., *et al.*, 2012. New Downlink Scheduling Framework for Hybrid Unicast and Multicast Traffic in WiMAX Networks, International Journal of Wireless and Microwave Technologies (IJWMT), 2: 69.

Kumar, N., *et al.*, 2011. DBAM: Novel User Based Bandwidth Allocation Mechanism in WiMAX, in Computer Networks and Information Technologies, V. Das, *et al.*, Eds., ed: Springer Berlin Heidelberg, 142: 229-236.

Kuo, W.H., *et al.*, 2011. Adaptive resource allocation for layer-encoded IPTV multicasting in IEEE 802.16 WiMAX wireless networks, Multimedia, IEEE Transactions on, 13: 116-124.

Malik, G. and F. Zafar, 2013. An Efficient downlink resource allocation in 802.16 WiMAX by using by updated dynamic recourse allocation algorithm, Science International, 25.

Misra, S., *et al.*, 2013. Routing bandwidth guaranteed paths for traffic engineering in WiMAX mesh networks, International Journal of Communication Systems, pp. n/a-n/a.

Mowafi, M.Y., *et al.*, 2012. Cognitive Radio Based Bandwidth Allocation Scheme for WiMAX Networks, Journal of Communications, 7.

Nasser, N., *et al.*, 2011. Utility optimized bandwidth allocation in WiMAX networks, in Wireless Communications and Mobile Computing Conference (IWCMC), 2011 7th International, pp: 540-545.

New, W., *et al.*, 2013. WiMAX: Performance Analysis and Enhancement of Real-time Bandwidth Request, IAENG International Journal of Computer Science, 40.

Nguyen, H.D., 2011. Deployment & scheduling in Wimax with relays: IEEE802. 16j, Evry-Val d'Essonne.

Sheu, J.P., *et al.*, 2013. A resource allocation scheme for scalable video multicast in WiMAX relay networks, Mobile Computing, IEEE Transactions on, 12: 90-104.

Shu'aibu, D., *et al.*, 2010. Partition-Based Bandwidth Management for Mobile WiMAX IEEE802. 16e, International Review on Computers & Software, 5.

Verma, R. and P. Garg, 2013. Interpretation of IEEE 802.16 e (Wimax), GJCST-E: Network, Web & Security, 13.