Journal of Telecommunication, Electronic and Computer Engineering
ISSN: 2180 – 1843 e-ISSN: 2289-8131 Vol. 14 No. 2
jtec.utem.edu.my

Effective Utilization of An Unused Bandwidth in IEEE 802.16 Network

Adamu Abubakar[1], Sanjir Inam Salsabil[1], and Ibrahim A. Lawal[2]
[1]*Deparment of Computer Science, International Islamic University Malaysia, 53100, Kuala Lumpur, Malaysia.*
[2]*Department of Information Technology, Bayero University Kano, Nigeria.*
adamu@iium.edu.my

Article Info

Article history:
Received June 13th, 2022
Revised June 20th, 2022
Accepted June 30th, 2022

Index Terms:
Unused bandwidth
Recycling
Transmission Rate
Scheduling

Abstract

A large percentage of available bandwidth in IEEE 802.16 networks can be utilised by using previous unused bandwidth. This is a common problem that occurs inside IEEE 802.16 networks, and it manifests itself when a subscriber station in an IEEE 802.16 network's Quality of Service (QOS) assured services is unable to predict how much data is being held back as unused bandwidth. As a direct consequence of this fact, the ongoing research has proposed simulating the process by which the remainder of the reserved bandwidth that is not being used will be recycled in order to enhance the Quality of Service and preserve the existing bandwidth reservation. Therefore, it was conceived that bandwidth might be reserved in the subscriber station separately from the bandwidth that is used for the downlink and the uplink of data transmission. This would prevent wasting the bandwidth. Through the utilization of an appropriate scheduling strategy associated with Round Robin, a simulation of an allocation of unoccupied bandwidth was carried out. The simulation findings reveal that an optimised bandwidth can ensure that the model can recycle 50–60 percent of the average amount of idle bandwidth. This is achieved through the allocation of unused bandwidth scheduling techniques. The findings of this research have demonstrated that it is possible to estimate the amount of data that is set aside as unused bandwidth and reuse it.

I. INTRODUCTION

WiMAX is a standard for wireless communications that was developed to construct metropolitan area networks (MANs). These networks have a range of up to 50 kkilometer (31 mile) [1]. It is a standard for Worldwide Interoperability for Microwave Access, and it offers users a variety of benefits in addition to increased bandwidth and a greater range for the use of data and multimedia applications. This standard was developed by the IEEE, specifically, the WiMAX Foruorganizatioganisation that initially developed WiMAX. The fourth generation of technology is currently being used to power wireless internet connections. The medium access control (MAC) layer and the physical layer (PHY) are the two layers that stand out the most in the WiMAX protocol, which is specified in the IEEE 802.16 standard [2]. The WiMAX protocol is made up of multiple layers. Before any data transfer can take place, the subscriber station (SS) must first reserve the necessary amount of bandwidth from the base station (BS) in order for variable bit rate (VBR) service to be provided [3]. This must be done before any data can be transferred. Because of this, it is now feasible to keep up the quality of service (QOS) that has already been established.

The first version of the standard (IEEE 802.16) that WiMAX is based on provided a physical layer for its operation that had a frequency range that went from 10 to 66 GHz [2-4]. The operation of WiMAX dwell on the media access controller (MAC) that makes use of a scheduling algorithm, and the subscriber station in order to obtain initial entry into a network [5]. The base station will then assign an access slot to the subscriber station once it has been determined that the station is eligible to enter the network [6]. The time slot may expand or contract, but it will always be assigned to the subscriber station. This implies that other subscribers will not be able to use the time slot [2]. The scheduling algorithm can be made efficiently with bandwidth in addition to being stable under load conditions such as overload and oversubscription [4]. The scheduling technique also enables the base station to adjust the Quality of Service (QoS) parameters by achieving a balance between the application needs of the subscriber station and the time-slot assignments [7]. This is carried out as part of the routine transmission that takes place in a network.

The Subscriber Station, often known as the SS, is a piece of standardised hardware that is utilised in the process of establishing communication between the subscriber and the base station. Each and every subscriber station is connected with the base station, and the subscriber station is able to reserve bandwidth thanks to the base station [8]. The reserve of bandwidth is a critical component of the data transmission process. Transmission SS (TS) is one type of SS that posses the capacity to transfer data from one set of storage space to another set of storage space. For the utilisation variable bit rates application, the amount of data that is received will fluctuate [6-8].

When the infrastructure of the WIMAX network is taken into consideration, any person who is able to subscribe to the service has the potential to benefit from its extensive service scope. This presents a challenge for research due to the fact that a significant number of subscribers pay for a service but do not make full use of it in their daily lives. Subscribers will be able to rest easy knowing that they will be able to make full use of any additional bandwidth that is a component of their existing plan, which will result in cost and resource savings for them as a result. As a result of this, the current research has established that locations with unstable Internet connections will find it helpful to have the capability to effectively utilise the bandwidth that they pay for and to be able to manage their additional bandwidth, while at the same time maintaining their quality of service as well as their experience. This may occur if the amount of bandwidth that was paid for within a certain time period has been left unused, and we now want to reclaim it so that it can be used. In this case, we will charge you for the amount of bandwidth that was paid.

In order to design a system that is capable of reclaiming subscribed service, both algorithms and protocols have been utilised [9-10]. By utilising the scheduling algorithms that are a part of the IEEE 802.16 protocol, a network's throughput, as well as its efficiency and accuracy, can be significantly improved [4]. It is possible to utilise both algorithms and protocols when developing an appropriate system. This allows for more flexibility in the design process. This will ensure that the reclaimed broadband is used effectively, and it will also maintain accuracy and throughput by utilising the scheduling algorithms in conjunction with the IEEE 802.16 protocol [6]. This will ensure that the reclaimed broadband is effectively used. It is possible for this current research to conceptualise each transmission from the subscriber station to employ bandwidth recycling to make use of the unused bandwidth while the data is being transmitted due to the fact that the complementary station is responsible for maintaining the complementary list in order for it to be pre-assigned to the base station in WIMAX operation. This is because the complementary station is responsible for maintaining the complementary list in order for it to be pre-assigned.

II. RELATED WORK

The Internet connectivity of mobile WiFi users is enhanced when WiMax and wireless broadband networks are integrated to give customers with dependable Internet access. Protocol adaptation, service quality support, and bandwidth share pricing must be handled at this time. Multiple service providers may run the WiMAX backbone network and WiFi access points.

According to Alfaisaly et al. [11], there are still a lot of challenges associated with WIMAX that need to be conquered before a dependable and high-quality audio connection can be established over the internet. Because of this, the focus of their research is on determining whether or not there is a distinction in the route taken by mobile devices while traversing the WiMAX network. The investigation makes use of a four-cell scenario, with a minimum of one mobile station and one base station set up in each cell. This is the bare minimum requirement. According to the findings, an optimal "VoIP" performance was improved in terms of the efficacy of the network as a result of the proximity of the mobile node to the base station. This improvement was brought about by the fact that the network was more efficient. Gupta and Chandavarkar [12] take a different approach and recognise that IEEE 802.16 WiMAX is composed of five service classes that each have their own distinct priorities. The priority of traffic that is in real time is higher than that of traffic that is not in real time. Because there is a finite amount of bandwidth, it needs to be reserved in advance in order to ensure that the throughput of real-time traffic is not hindered by the WiMAX network. The research presented a dynamic bandwidth allocation algorithm as a workaround for the fact that the WiMAX standard does not provide any algorithm for dynamically allocating bandwidth to the services that are being discussed. According to the findings, a balancing that was associated with an increase and decrease of bandwidth sufficient for the requirements of the transmission was achieved by increasing the throughput of real-time traffic as the bandwidth is handled efficiently. This was performed in order to comply with the requirements of the transmission.

According to the findings of the research conducted by Niyato and Hossain [13], broadband wireless access networks that are based on WiMAX are capable in offering backhaul support for mobile WiFi hotspots. As a consequence of this, the research looks into the possibility of creating a shared integrated WiMAX and WiFi network. The results of the performance evaluation show positive results. Chuck and Chang [14] proposed a scheme for recycling unused bandwidth in IEEE 802.16 networks. The goal of this scheme was to support bandwidth-demanding applications with quality of service (QoS) by recycling unused bandwidth without altering the already established bandwidth reservation. According to the findings of the research, the introduction of the discovery results in an increase of forty percent in the overall throughput when the network is functioning normally.

For IEEE 802.16 broadband wireless networks, a cross-layer framework has been designed to efficiently allocate resources to various classes of traffic using a fair adaptive cross-layer resource allocation scheme. This framework is designed to perform such technique with a cross-layer resource allocation scheme. According to the findings, the MAC layer is responsible for handling bandwidth allocation, whereas the Physical layer is responsible for handling burst allocation [15]. Mobility across WiMAX and 3GPP access can become seamless and efficient, and there is no need for mobile terminals to support simultaneous transmission on both types of access [16]. This is due to the integration of mobile WiMAX into evolved 3GPP networks is a compelling approach for providing wireless broadband services. Adekar and Kureshi [17] did research on the performance analysis of heterogeneous systems involving IEEE 802.11 and IEEE 802.16. Scheme for the reservation of bandwidth and the degradation of quality utilising call admission control Mobile WiMAX networks are something that Saidu et al [18] have proposed. The results of the simulation show that the proposed scheme significantly improves the efficiency of the network in comparison to other schemes, both in terms of ensuring the quality of service for all service classes and accepting a greater number of connections into the network. In addition, Deva Priya and colleagues [19] have proposed dynamic resource-aware scheduling schemes for use in IEEE 802.16 broadband wireless networks. While still catering to the specific traffic flows that are being addressed, the scheme enables a greater number of packets to be serviced in the same round. In addition, Wisdom et al. [20] employed the actual variant traffic characteristics appropriately, with a well-designed threshold, in order to minimise needless delay while aligning the traffic. This helps the researchers achieve their goal of minimising the unnecessary delay.

A spectral analysis of the queueing model for IEEE 802.16 wireless networks was developed by Feng [21]. The method uses spectral analysis to process a steady state probability, and then it obtains few key performance measures such as system efficiency, loss probability, and the mean number of packets in the buffer. The method also takes into account the contents of the buffer, as well as the backoff stage and the backoff counter. Varthan and Vignesh [22] have conducted research on a dynamic resource-aware scheduling scheme for IEEE 802.16 broadband wireless networks. In a similar vein, Mou and Srivastava [23] looked into the potential applications of IEEE 802.16 for the Internet of Things (IoT).

Mokeresete and Esiefarienrhe [24] demonstrated that the WiMAX IEEE 802.16 standard can be applied to problems with last-mile connectivity in order to provide a solution. According to the findings, WiMAX IEEE 802.16e is a better option for locations with a high population density. Additionally, it could resolve the difficulties that come with the development of infrastructure in rural areas and provide the necessary access to high-speed connectivity. Huang et al. [25] conducted research on this problem. In addition, Chu et al. [26] developed a QoS architecture that was applied to the MAC protocol of IEEE 802.16. An architecture for implementing the IEEE 802.16e transmitter and receiver physical (PHY) layer on field-programmable gate arrays has been proposed by Joodaki et al. [27]. The practical time-synchronized transmit and receive pairs communication with real modems demonstrates that the proposed system can be effectively implemented in real-time.

Utilization of unused bandwidth in IEEE 802.16 networks in an effective manner continues to be a significant challenge. In spite of the fact that Chuck and Chang [14] developed a technique for recycling unused bandwidth in IEEE 802.16 networks, the objective of this scheme was to support bandwidth-demanding applications based on expectations rather than to detect and respond to changes in bandwidth usage. Similar to research entities that linked with underutilised WIMAX bandwidth centre on deterministic allocations of bandwidth based on similar indiscernibility relations, this phrase describes the focus of these studies. The inadequacy of the parameterization tools is still an outstanding concern when assessing these procedures; nevertheless, these predicaments can be alleviated by applying the principles of automatic detection. It is important to point out that the aforementioned works [14-20] continue to concentrate on a rigid scheduling standard. Despite this, there has not been a lot of discussion about the best way to use detection of balanced allocation of unsegmented bandwidth in WIMAX for practical applications. Therefore, as a result of the past successful applications that Chuck and Chang [14] have had for recycling unused bandwidth, which has motivated the studies of [14-27], this study provides strategies on Effective Utilization of An Unused Bandwidth in IEEE 802.16 Networks.

III. METHODOLOGY

Bandwidth utilisation is improved by scheduling. Despite the provision of many scheduling algorithm, yet there are still improvement that is put forward by each research. This current study methodological approach lies in simulations of proposed concept. The concept lies with bandwidth reservation and setting of limit bandwidthith to improved quality of service. In this frame, the complementary station (CS) is holding out hope that it will have the chance to recycle any unused bandwidth that is being transmitted by its corresponding transmitting station (TS). The complementary list, also known as a CL, is produced by the base station BS, which is also the location where all of the scheduling information is kept. The mapping relation that exists between each pre-assigned pair of CS and TS is included in the CL. The plan that we have proposed is broken up into two parts: establishing a hierarchy for the data transmission to accepting substations through the utilisation of protocol and scheduling approach. Within the framework of the protocol, the relevant transmitting station (TS) is responsible for sending the unused bandwidth to its corresponding control station (CS). This gives the CS the ability to make use of the bandwidth whenever it is required. The technique for scheduling provides the BS with assistance in selecting a CS to correspond with each TS.

A. Experimental Setup

Establishing a network connection by means of a base station (BS) and a subscriber station (SS), with the intention of distributing it in a uniform manner is the crucial aspect of the experiment set out for this study. The multiple protocols' functionality can be observed in simulation mode. The simulation scenario is established for services utilising numerous WIMAX transmission session. This scenario dwells on the estalishiment of BS and SS (see Figure 1). In the first step, the Base Station and subscriber Stations are set up, and the nodes are connected.

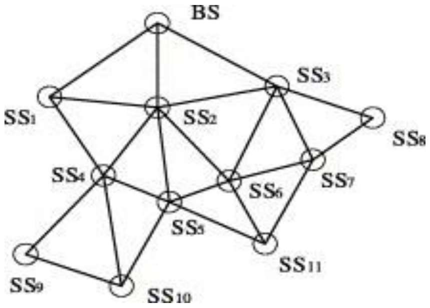

Figure 1. Primary Setup for Base station with Subscriber Stations

Figure 2 illustrates the complete experimental stages, and it provides a detailed description of the labor-intensive approach utilised in network modelling. The process began with the initialization of the nodes in the WiMAX networks. Checking the availability of networks is the first step, although this procedure is dependent on whether or not networks are available. If the network is available, then it will proceed immediately to the next step, which is to determine whether or not more than one network is available. In the event that "Yes" is selected, the QoS parameter will be determined using the bandwidth packet delay for each of the accessible networks.

In the event that it is "No," it will hold off on establishing communication until it can do so from a single network.

Regardless of the availability of networks, it will check to see whether there is another subscriber station (SS), connected to the base station in a network topology that has sufficient bandwidth, and it will determine whether or not that SS is available. If there is no SS accessible, then there will be no communication, and the procedure will finish successfully. If there is SS available, then it will be able to establish a connection from WiMAX.

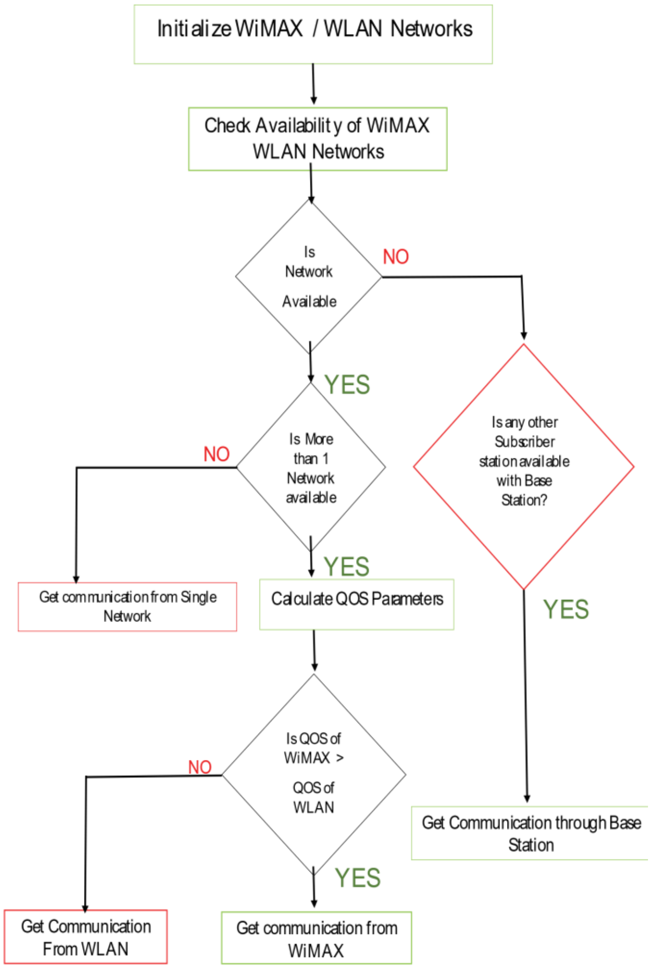

Figure 2. The Proposed Methodological Approach

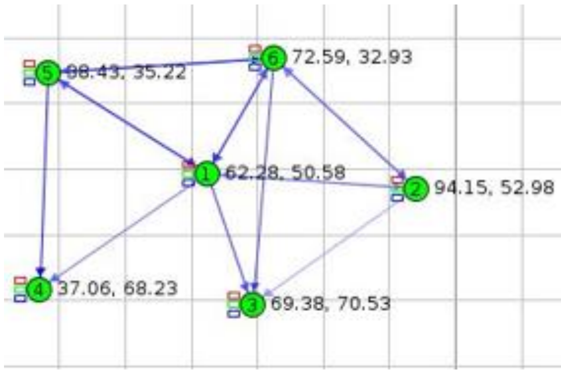

Figure 3 Simulation Setup with BS & SS

After the connection has been established and the sending and receiving of packets have begun, check for any updates and the proportion of bandwidth that is being used, and finally, begin the process of collecting data from the Base station to the other nodes of Subscriber stations that are still active (see Figure 4).

Figure 4. Collecting data from the BS from the nodes of SS

WIMAX's plans for the future include focusing at least in part on expanding wireless internet access for the general public. This could be applicable to various aspects of startup businesses that rely heavily on wireless technology as their primary tool. WiMAX might be implemented in a wide variety of locations, including those that rely heavily on wireless networks as a source of Internet access. Some examples of these locations are hotels, restaurants, and coffee shops. Similar to Wi-Fi hot spots work mechanism, but using WiMAX technology, high-speed wireless broadband internet services can be made available across a significantly broader geographic region.

IV. PRESENTATION OF RESULTS AND DISCUSSION

The first step involves the installation of the Base Station as well as the subscriber Stations, followed by the connection of the nodes, and finally the simulation (see Figure 3).

Only once the network has been initialised is the transmission schedule generated, and data communication is carried out in accordance with network performance criteria for as long as the network is operational.

After the network topology has been constructed and available for collect data, l, once the data collection process has been completed, initiate the sending of packets from the Base station to one or more subscriber stations. Through the execution of this method, it will be ensured that the network topology is successfully receiving a message from each of its connected nodes. In addition, the values of the locations held by each subscriber station are indicated by the Node information, in addition to the amount of packet loss or data that was received. This important information will help to build up the structural output of the existing network architecture in order to show theoptimize optimised path to recycle the unused data. This path will indicate the shortest path to recycle the data (see Figure 5 and 6).

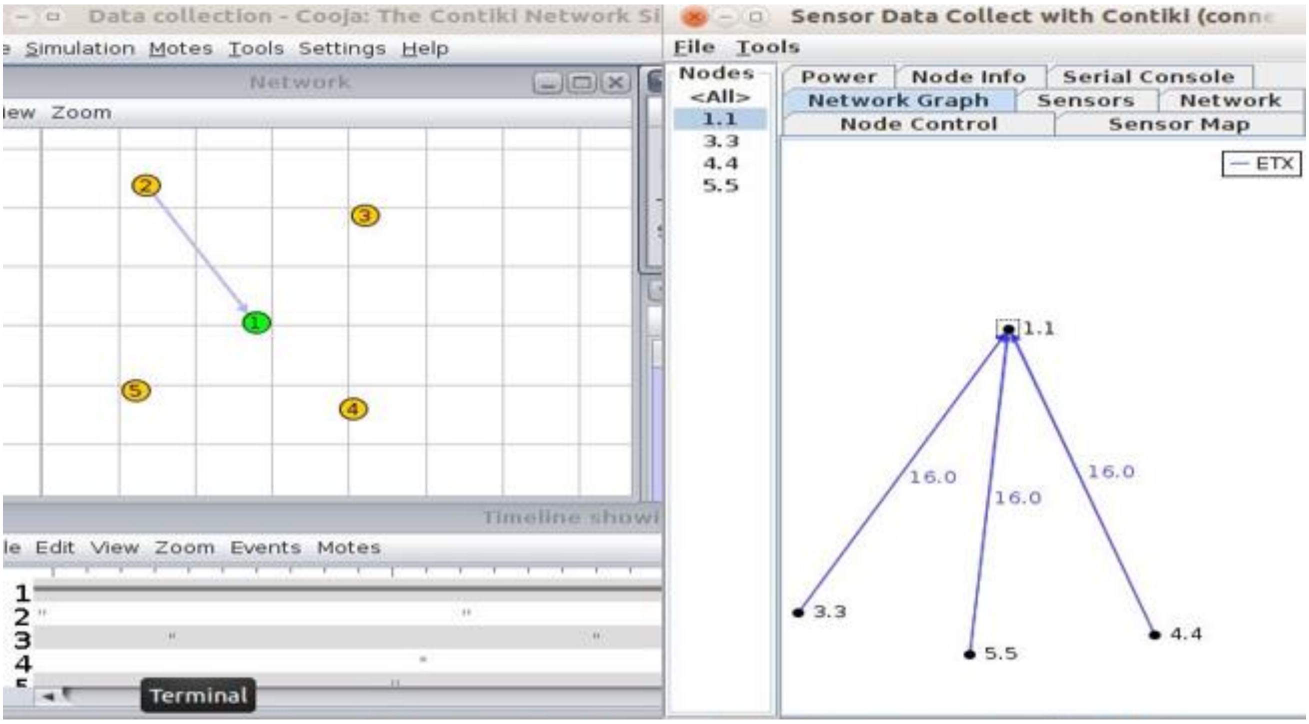

Figure 5 The Configuration of the Simulation Scenario

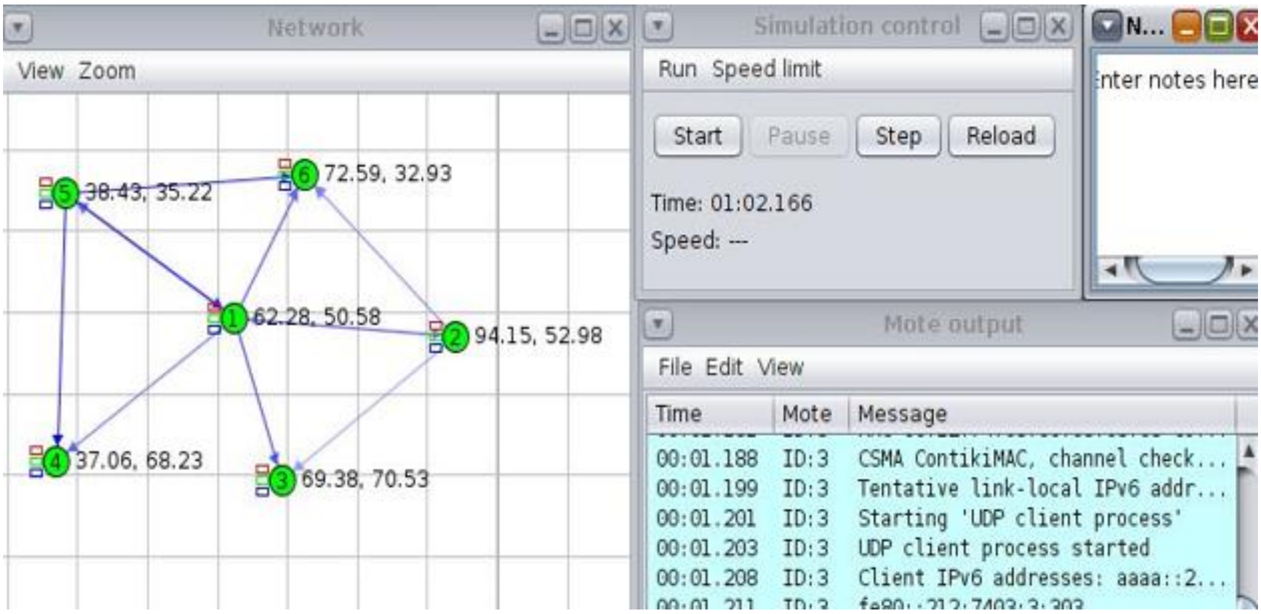

Figure 6 The Exscution of the Simulation Scinario

In order to demonstrate how the simulation technique is executed and how it successfully runs to maintain the quality of service while sorting the technique according to criteria, a further analysis is necessary. In the end, the maximum possible recycling of bandwidth that is accomplished without compromising the quality of service and with additional delay can be eliConsidering the high expectation for an improved performance measure, another simulation was carried out. This will be able to improve accuracy while simultaneously comparing it with other methods that are available in use to evaluate throughput and develop the overall simulation performance (See Figure 7).

Journal of Telecommunication, Electronic and Computer Engineering
ISSN: 2180 – 1843 e-ISSN: 2289-8131 Vol. 14 No. 2
jtec.utem.edu.my

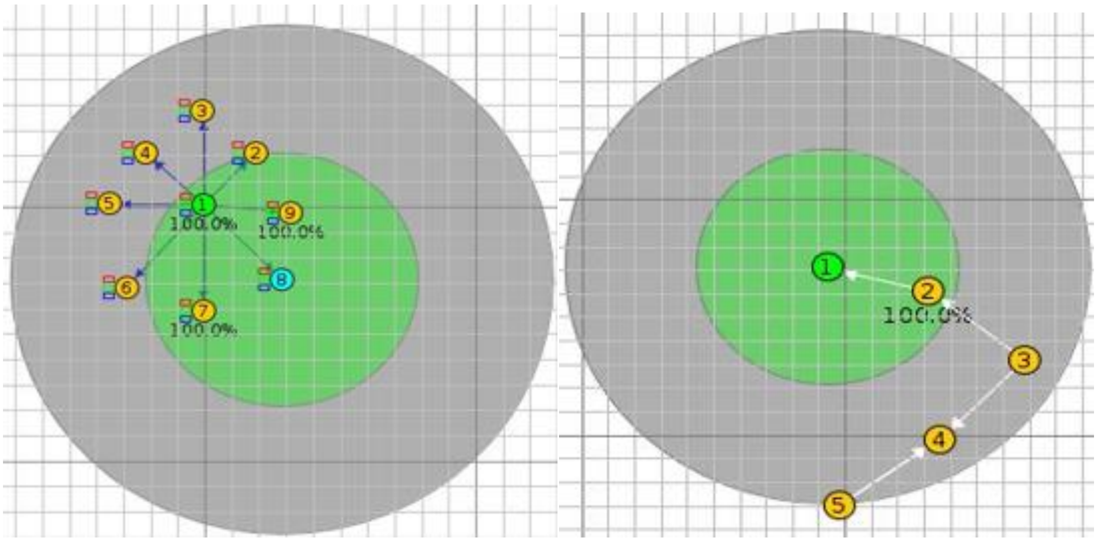

Figure 7 The design implementation is based on the Quality of Services

This research attempts to provide the highest possible bandwidth rate in an efficient manner by guaranteeing that the quality of services provided by the bandwidth that was previously available is maintained. The results of this research show that a higher accuracy rate can be depicted through scheduling. While at the same time allowing the Base station to schedule a Complementary station Round Robin Scheduling algorithm utilising dynamic bandwidth allocation in order to recycle the unused bandwidth.

The simulation progress is also demonstrated here, and the simulation analysis provides outcomes that increase the accuracy from 40 percent to 50 percent. The results of the simulation can be seen in a graphical representation of the network topology, which was generated after the experiment was completed.

Our mathematical and simulation results will show that not only does our strategy boost throughput gain (overall performance), but it also will reduce delay without compromising the quality of service requirements. This will be shown to be the case by both methods. The simulations that should be expected for the planned improvements in the future are shown here in the graphic that can be found in Figure 7.

The simulation is carried out with the assistance of the Instant Contiki OS environment, which enables the Cooja Networking simulator to display the prototype model of the network simulation running in the VMware operating system with enhancements including a wireless network, memory, and processing like sensors (see Figure 8).

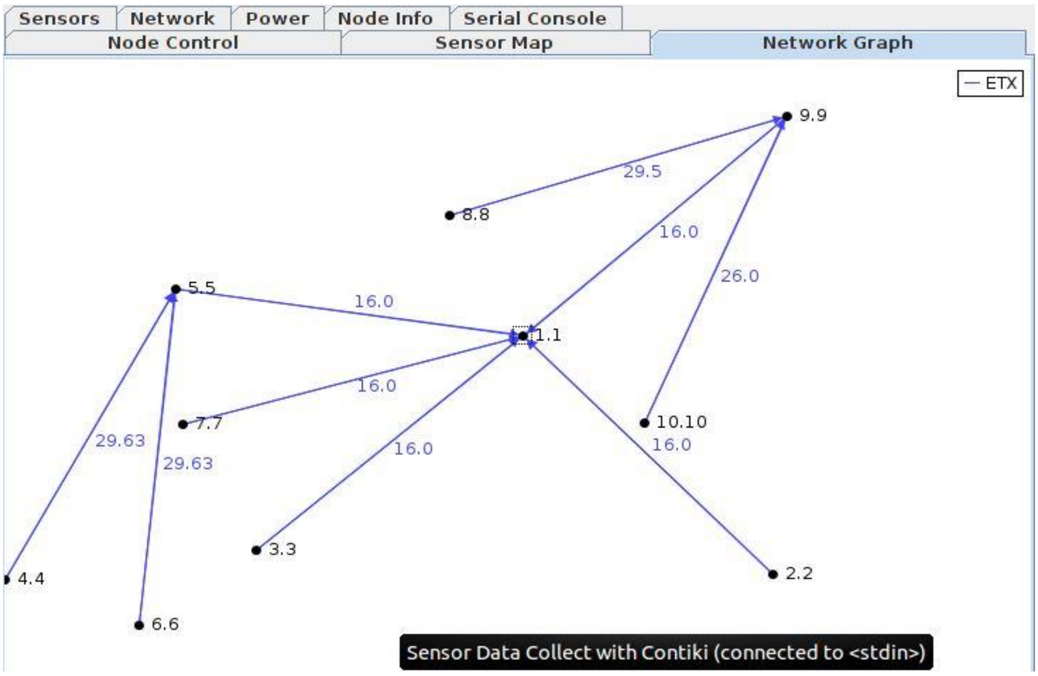

Figure 8 The Final Structural Output of Network Graph

Figure 8 is the comprehensive structural output that was automatically generated by the Cooja networking simulator using machine learning. It is a representation of all of the nodes that are linked to the Base Station and are used during the process of gathering raw data. The accumulation of data that is undesiredresults in an enhanced representation of the structure output. This improved representation is then used to find the most efficient way to recycle the unwanted data in a precise manner.

This research helps to enhance the recycling rate of available bandwidth by ensuring that the quality of service is maintained. In this particular instance, the expected simulations for the intended upgrade are presented down below in Figure 9, and the typical quantity of power that has been expended is used to evaluate extra accuracy.

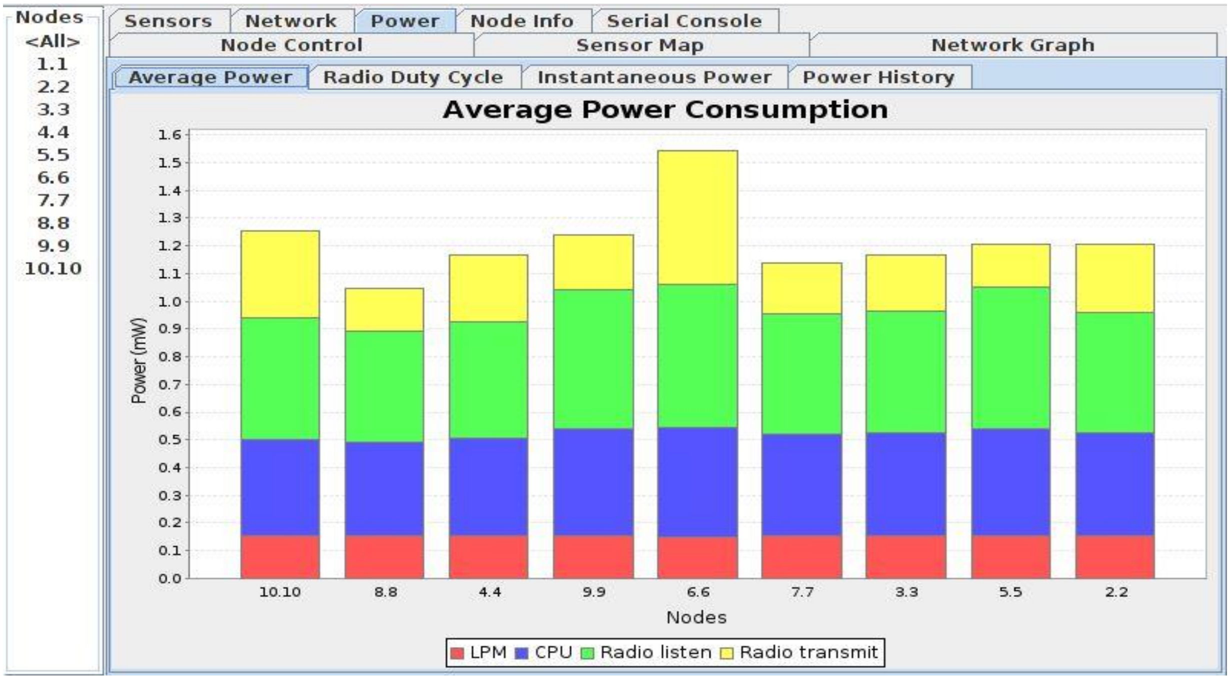

Figure 9 The Average Power Consumed

When the packets of involves in the transmission are forwarded over the transmission session, it can be identified and measure the resources that are used. The capacity of a certain source can be determined by the effective bandwidth of that source. During the course of the simulation analysis, the WiMAX network was taken into consideration. In our simulation, a total of 10 nodes are used, none of which have a fixed variable size, and we have ensured that there is no longer any additional latency.

After careful consideration, it has become amply clear that maximising usage of unused bandwidth in IEEE 802.16 networks presents a formidable task. Because of this, the study recommended carrying out the task. Despite the fact that methods for recycling wasted bandwidth in IEEE 802.16 networks are essential to supporting bandwidth-demanding applications that are based on detection rather than expectations, this aspect of the study is quite important. At the very least, one of the priorities that WIMAX has set for itself for the foreseeable future is to increase the number of people who have access to wireless internet. This may be relevant to a variety of features of start-up enterprises, particularly those that depend significantly on wireless technology as their primary tool. WiMAX might be deployed in a huge range of settings, including some that rely largely on wireless networks as a means by which to access the internet. Airports, convention centres, hotels, restaurants, and coffee shops are some examples of the kind of establishments that fall under this category.

V. CONCLUSION

This study demonstrates that RRSA has improved the throughput gain and enhanced the reprocessing efficiency. On the other hand, this algorithm decreases the additional delay by satisfactorily ensuring the actual quality of the services that are guaranteed. For efficient use of the available bandwidth, it is recommended to use the Round Robin Scheduling Algorithm with the Dynamic bandwidth request-allocation technique. This allows the recycling of the unused bandwidth so that it can be set to productive use. According to the findings of both the scientific studies and the simulations, the Proposed Round Robin Scheduling Algorithm using the Dynamic bandwidth request-allocation approach scheme increased the throughput while simultaneously decreasing the delay with only a trivial increase in overhead. It also satisfied the QoS requirements and ensured that services would be provided. Bandwidth is occupied to reprocess the unused bandwidth once it happens and also provide effective output to gain the highest accuracy rates. This is accomplished with the Round Robin Scheduling Algorithm using Dynamic bandwidth request-allocation approach, which is implemented and presented in this project. Achieving the success rate of effective bandwidth utilisation is essential to achieving this project's goal of effectively utilising bandwidth.

REFERENCES

[1] A.B. Ibrahim, C.Z. Zulkifli, S.A. Ariffin, & N.H. Kahar. High frequency of low noise amplifier architecture for WiMAX application: A review. International Journal of Electrical & Computer Engineering (2088-8708), 11(3), 2021.

[2] A. Ahson, Syed, and I. Mohammad, eds. WiMAX: Standards and security. CRC press, 2018.

[3] O. Benkhadda, S. Ahmad, M. Saih, K. Chaji, A. Reha, A. Ghaffar, S. Khan, M. Alibakhshikenari, and E. Limiti. Compact Broadband Antenna with Vicsek Fractal Slots for WLAN and WiMAX Applications. Applied Sciences, 12(3), 2022, pp.1142.

[4] N.B. Mohamadwasel, N. B., & Abdala, M. A. (2020). Design of WiMAX Network for Istanbul Universities With OPNET. Informatica: Journal of Applied Machines Electrical Electronics Computer Science and Communication Systems, 1(1), 2020, pp. 1-9.

[5] M. Hasan, M.R.I. Faruque, & M.T. Islam. Dual band metamaterial antenna for LTE/bluetooth/WiMAX system. Scientific reports, 8(1), 2018, 1-17.

[6] S. Jagatheswari, P. Ramalingam, & J. Chandra Priya. Improved grey relational analysis-based TOPSIS method for cooperation enforcing scheme to guarantee quality of service in MANETs. International Journal of Information Technology, 14(2), 2022, pp.887-897.

[7] H.R. Abdulshaheed, Z.T. Yaseen, A.M. Salman, & I. Al_Barazanchi. A survey on the use of wimax and wi-fi on vehicular ad-hoc networks (vanets). In IOP Conference Series: Materials Science and Engineering 870(1), 2020, pp. 012122. IOP Publishing.

[8] N. Mouawad, R. Naja, & S. Tohme.. Quality of Service Provisioning for Ambulance Tele-medicine in a Slice-based 5G Network. In 5G Impact on Biomedical Engineering 2022, pp. 73-90. CRC Press.

[9] C. Bai, P. Yan, X. Yu, & J. Guo. Learning-based resilience guarantee for multi-uav collaborative qos management. Pattern Recognition, 122, 2022, pp. 108166.

[10] Q. Jiang, V.C. Leung, & H. Tang. Statistical QoS-Guaranteed Traffic Rate Adaptation for Wireless Scalable Video Streaming. IEEE Systems Journal, 2022.

[11] N.N. Alfaisaly, S.Q. Naeem, & E.K. Jassim. The Effect of Different Mobile Trajectory on the Performance of VoIP Application in WiMAX Network. In 2022 9th International Conference on Electrical and Electronics Engineering (ICEEE), 2022, pp. 141-146).

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

[13] D. Niyato & E. Hossain. Wireless broadband access: Wimax and beyond-integration of wimax and wifi: Optimal pricing for bandwidth sharing. IEEE communications Magazine, 45(5), 2007, pp.140-146.

[14] D. Chuck & J.M. Chang. Bandwidth recycling in IEEE 802.16 networks. IEEE Transactions on Mobile Computing, 9(10), 2010, pp. 1451-1464.

[15] M. Deva Priya, M. Sangeetha, A. Christy Jeba Malar, E. Dhivyaprabha, N. Kiruthiga, & P.L. Rajarajeswari. Fair adaptive cross-layer resource allocation scheme for IEEE 802.16 broadband wireless networks. Wireless Personal Communications, 117(4), 2021, pp. 2645-2666.

[16] P. Taaghol, A.K. Salkintzis & J. Iyer. Seamless integration of mobile WiMAX in 3GPP networks. IEEE Communications Magazine, 46(10), 2008, pp.74-85.

[17] R.H. Adekar, & A.K. Kureshi. Performance Analysis of Heterogeneous Systems Ieee 802.11 and Ieee 802.16 Using Spectrum Sharing Mechanism. In Advanced Engineering Forum, 44, 2022, pp. 127-135. Trans Tech Publications Ltd.

[18] I. Saidu, S. Subramaniam, A. Jaafar, & Z.A. Zukarnain. A QoS-Aware CAC with bandwidth reservation and degradation scheme in IEEE 802.16 e networks. Wireless Personal Communications, 82(4), 2015, 2673-2693.

[19] M. Deva Priya, A. Christy Jeba Malar, S. Sam Peter, G. Sandhya, L.R. Vishnu Varthan, & R. Vignesh. Dynamic Resource Aware Scheduling Schemes for IEEE 802.16 Broadband Wireless Networks. In Progress in Advanced Computing and Intelligent Engineering, 2021, pp. 218-230. Springer, Singapore.

[20] D.D. Wisdom, A.E. Ajayi, C.U. Arinze, H. Idris, U.M. Bello & I.O. Aladesote. An Optimized TWIN Battery Resource Management Scheme in IEEE 802.16 e Networks. In Proceedings of Sixth International Congress on Information and Communication Technology, 2022, pp. 73-95. Springer, Singapore.

[21] W. Feng. Spectral Analysis of the Queueing Model for IEEE 802.16 Wireless Networks. Wireless Personal Communications, 121(3), 2021, pp. 2073-2110.

[22] L.V. Varthan & R. Vignesh. Dynamic Resource Aware Scheduling Schemes for IEEE 802.16 Broadband Wireless Networks. Progress in Advanced Computing and Intelligent Engineering: Proceedings of ICACIE 2019, 1(1), 218.

[23] T.D. Mou, & G. Srivastava. Network Protocols for the Internet of Health Things. In Intelligent Internet of Things for Healthcare and Industry, 2022 pp. 21-66. Springer, Cham.

[24] M. Mokeresete, & B.M. Esiefarienrhe. Can the WiMAX IEEE 802.16 Standard Be Used to Resolve Last-Mile Connectivity Issues in Botswana?. In Telecom 3(1), 2022, pp. 150-162. MDPI.

[25] S.C. Huang, R.H. Jan & C. Chen. Energy efficient scheduling with QoS guarantee for IEEE 802.16 e broadband wireless access networks. In Proceedings of the 2007 international conference on Wireless communications and mobile computing, 2007, pp. 547-552.

[26] G. Chu, D. Wang, & S. Mei. A QoS architecture for the MAC protocol of IEEE 802.16 BWA system. In IEEE 2002 International Conference on Communications, Circuits and Systems and West Sino Expositions, 1, 2002, pp. 435-439.

[27] S. Joodaki, M. Fardad, S. Alghasi, S. Jafari, & H. Moeini. Implementation of IEEE 802.16 e standard on Xilinx ZC706: A C-RAN prototype. Wireless Personal Communications, 116(3), 2021, 2187-2204.