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# Comparative Analysis of Scheduling Algorithms in IEEE 802.16 WiMAX

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**Abstract:** With the advancements in technology, need for Broadband Wireless Access (BWA) increase due to user mobility and requirement to access data all the time. The best available quality of experience is provided by IEEE 802.16 WiMAX networks. For guaranteed provision of services like voice, video and data IEEE 802.16 WiMAX include several Quality of Service (QoS) options on Media Access Control (MAC) layer. In this paper, a comparative analysis of different scheduling algorithms through simulation is provided with the help of buffer utilization and queuing delay. Four data traffic types selected in this simulation scenario and OPNET Modeler has been used to simulate different network scenarios for WiMAX scheduling. Our simulation results show that the MDRR performs best for all types of data traffic. However, other scheduling algorithms might perform well for high priority data traffic but not for the low priority due to unfairness issues.

**Keywords:**QoS, Resource Allocation, Scheduling Algorithms, WiMAX

## 1. Introduction

In late 90's Institute of Electrical and Electronics Engineering IEEE initiated a group to develop a standard that provide wireless broadband access in a region. Purpose behind this initiation was to replace the traditional Digital Subscriber Line (DSL) because it was lacking wireless access and due to wired system it become more complex in different situations. After some period first, standard was introduced by this group as IEEE 802.16 WiMAX, the Worldwide Interoperability for Microwave Access whose aim is to provide wireless data over large coverage areas as well as in local loop in a variety of ways. After introducing first standard IEEE issued several standards of WiMAX on regular basis with different services and supports.

WiMAX is based on IEEE 802.16 standard, that also known as Wireless MAN. IEEE 802.16 group was formed in 1998 to develop a standard for wireless broadband access. Initially, group's focus was to develop a LOS Point to Multipoint (PMP) wireless system in frequency ranges from 10 GHz to 66 GHz. First standard of IEEE 802.16 completed in December 2001. That was based on single carrier Physical (PHY) layer with burst Time Division Multiplexed (TDM) MAC layer [1].

After short period, IEEE 802.16 group announced 802.16a, which was an amendment to the original standard to include NLOS support on frequency ranges of 2 GHz to 11 GHz band. IEEE 802.16a use Orthogonal Frequency Division Multiplexing (OFDM) for Physical layer and there are some additions to the MAC layer also, such as support for Orthogonal Frequency Division Multiple Access (OFDMA) [2]. In 2004, a new version of IEEE 802.16 was introduced that was known as IEEE 802.16d or IEEE 802.16 2004. This introduced version replace all previous versions and formed the basis for first WiMAX solution referred to as fixed Wi-MAX. As this standard was based on fixed WiMAX, it has only LOS support and the operating frequencies were between 10 GHz to 66 GHz [3]. In December 2005, IEEE approved 802.16e 2005, an extension to IEEE 802.16d 2004 standard to provide support for mobility on existing standard [4]. IEEE 802.16e-2005 provide basis for WiMAX solution for nomadic and mobile applications and is referred to as mobile WiMAX. This mobility based standard of WiMAX has support for both Line of Sight (LOS) and Non Line of Sight (NLOS) and has operating frequencies in licensed band. Fig. 1 shows the basic overview of WiMAX comprising LOS and NLOS.

Physical Layer of WiMAX has support for several multiplexing techniques like Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) with wide bandwidth capacity of 1.25 MHz to 20 MHz for each channel. Also it has some wide frequency range 2 GHz to 11 GHz for NLOS and 10 GHz to 66 GHz for LOS on which it can operate. However due to equipment availability only few frequency bands are in use e.g., 2.4, 2.5, 3.5, 5 and 5.8 GHz.

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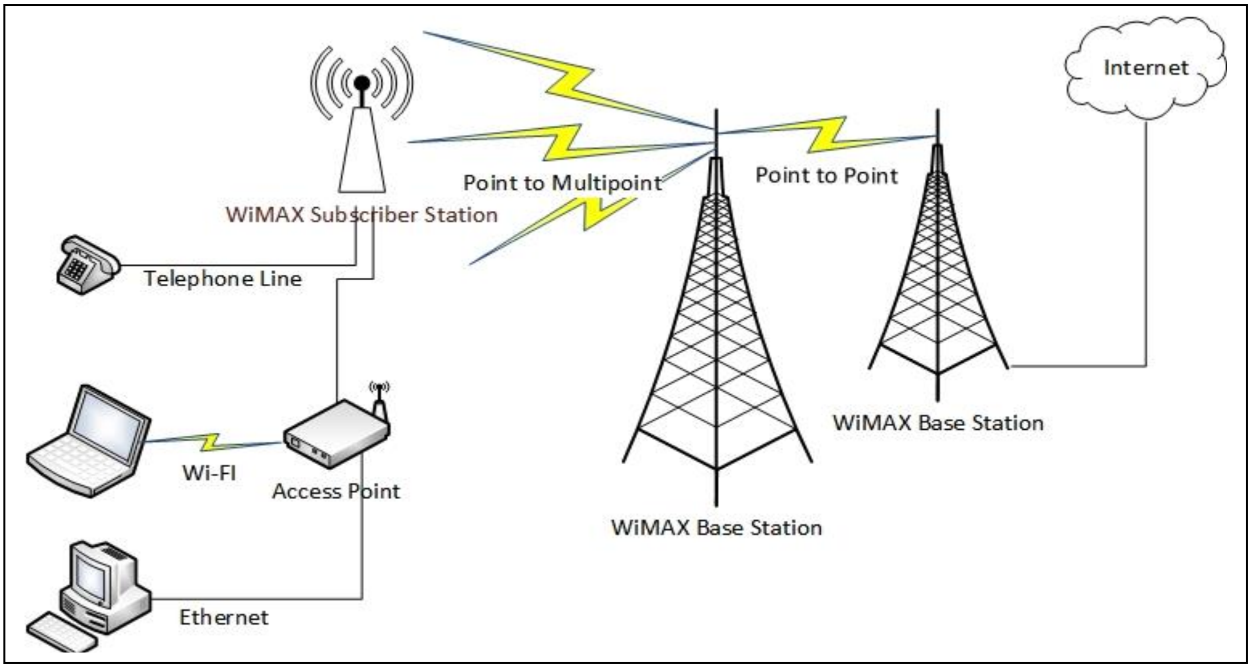


Figure. 1. Overview of WiMAX

WiMAX network consists of Base Station (BS) and Sub-scriber Station (SS), usually, BS connected with the backbone network through wired connection however, in some cases it might be in the form of wireless connection. Whereas, SS receive services from BS according to user requirements. WiMAX operates in two type of networking modes: Point to Multipoint (PMP) and Mesh Mode. In PMP mode, each SS in the network has a direct communication link with BS and SS's are not allowed to communicate directly with each other. Whereas, in case of Mesh mode, SS's might have direct communication with BS as well as can communicate with each other directly. Purpose behind this was to serve SS's that are in the depth coverage areas by using multihop links through intermediate SS's. WiMAX standard specifies two scheduling modes. In Centralized Scheduling BS acts as a central entity that perform all operations related to resource allocation and traffic scheduling. Whereas, in Distributed Scheduling, all SS's and BS's in the network participate in the process for scheduling and resource allocation. As all nodes compete with each other for network resources by using an election algorithm. Usually different traffic types and different nodes have different priorities in network for proper scheduling of network resources [5], [6].

IEEE 802.16 WiMAX standard specifies five different QoS service classes for differentiation between traffic classes to ensure the efficiency. Specified QoS classes are Unsolicited Grant Service (UGS), real time Polling Service (rtPS), extended real time Polling Service (ertPS), non-real time Polling Service (nrtPS) and Best Effort (BE).

In this paper, different scheduling algorithms for WiMAX has been discussed by considering different traffic types. Section 2 covers the related work and Section 3 presents brief discussion about QoS support in WiMAX network. Whereas, Section 4 includes brief introduction of scheduling algorithms used in simulations for comparison purpose. Section 5 and 6 shows the simulation setup and results. Section 7 presents conclusion.

## 2. Related Work

In [7], authors provide detailed survey about different scheduling algorithms for PMP WiMAX mode, as well as provide details about WiMAX service classes their applications and some performance evaluation parameters.

In [8], author evaluate various types of scheduling algorithms of WiMAX wireless networks e.g., Round Robin (RR), Strict-Priority (SP), Weighted-Fair Queuing (WFQ) and Weighted-Round Robin (WRR) etc., a brief introduction of WiMAX and QoS service classes is also given.

In [9], authors gives a comparative analysis of two different scheduling algorithms, Weighted Fair Queue (WFQ) and Priority Queue (PQ). Different issues like end to end delay and packet reception and transmission details are used to evaluate the algorithms.

In [10], author's major area of focus was on QoS analysis in WiMAX networks. It also includes information about various service flows and their applications defined by the IEEE 802.16 standard.

In [11], authors presents an approach based on a fully centralized scheduling scheme, where a global QoS agent collects all the necessary information on traffic flows, and takes decisions on traffic admission, scheduling, and re-source allocation. Then based on the complete global knowledge of the system, the deterministic QoS levels can be guaranteed. In terms of the scheduling discipline used for the various classes WFQ and FIFO are used. The strict priority discipline allows the redistribution of bandwidth among its active connections to lowest priority.

In [12], authors propose two level scheduling scheme called TLS that have support for fairness and quality of service for downlink traffic in WiMAX network. At first stage, High Priority packets classified according to their QoS classes by the scheduler. UGS have the highest priority and BE have the lowest priority whereas, ertPS, rtPS and nrtPS lies between them. Each classified QoS class have separate queues for packets and packets are placed into different priority queues according to their priority. It serves high priority queue until it is empty and then moves towards next lower second higher priority. Whereas, at second level, authors used a fairness scheduling scheme for different service flows. Fairness approach that used for rtPS and ertPS is Adaptive Proportional Fairness scheme. Proportional Fair-ness used for nrtPS and BE services whereas, UGS required fixed data rates due to this BS forward fixed size data packets at periodic intervals.

In [13], authors used FIFO, PQ and WFQ scheduling algorithms to schedule data traffic according to the QoS classes defined by the standard. Authors confirmed the performance of these algorithms by considering different QoS analysis parameters like Delay, Load and Throughput.

Previously, in all of these papers, authors consider QoS parameters like End to End delay, Throughput, Load and Delay, however, some authors have only define the parameters like buffer delay, buffer utilization. In this paper we consider Queuing Delay and Buffer utilization to evaluate performance in WiMAX.

## 3. QOS SUPPORT IN WIMAX

WiMAX MAC layer provides the interface functionality between higher layers and physical layer. It takes MAC Service Data Unit (MSDU) packets from higher layers and organize them into MAC Protocol Data Units (MPDUs) during reception and transmission process. As MAC protocols are based on connection orientation and all communication takes place through these connections. A simple connection is usually a logical link that provides connectivity between MAC layers of SS and BS. After connectivity, a set of services are mapped on the connection with defined levels of QoS for each service. In IEEE 802.16, QoS support is provided on the basis of per-connection mechanism and this connection is recognized by Connection IDentifier (CID), which resides in MAC PDU (MPDU). CID maps with a Service Flow IDentifier (SFID) that is used to define QoS specifications of a service flow which is associated with the connection. Every service flow, also has a set of specific associated QoS parameters for which memory and bandwidth resources reserved by BS and SS in uplink/downlink maps.

Established connection might have different types like, Basic Connection for communication of short messages, Primary Management Connection for long communication with delay acceptable support and last one is Secondary Management Connection for configuration data of SS and management messages of higher layers [3].

Parameters that can be associated with service flows are minimum reserved rate, traffic priority, tolerated jitter, maximum traffic burst, maximum sustained rate, scheduling service and maximum latency. However BS have right to create optional service class. Whereas, service class shows a specific set of QoS parameters. IEEE 802.16 WiMAX standard has define some of the following scheduling services:

### *A. Unsolicited Grant Service (UGS)*

UGS is used to enable support for real time services which has data packets of fixed size on periodic basis. Specifically used for VoIP, E1 and T1 links. This service type has fixed size data grants on periodic basis that reduces the latency and overhead on SS's Requests [3].

### *B. real time Polling Service (rtPS)*

It is used to enable support for real time services which has data packet of variable size on periodic basis. Specifically used for MPEG video where, applications run on real time but due to ups and down on frame ratio, data rates varies. This QoS service class offers more overhead as compare to UGS, this happens due to variable data rates [3].

### *C. extended real time Polling Service (ertPS)*

ertPS is a scheduling service mechanism that was introduced by using the efficiency of both rtPS and UGS. ertPS is specifically designed for real time traffic that operates on variable data rate. Such as VoIP with silence suppression.

### *D. non real time Polling Service (nrtPS)*

It provides unicast polling service on regular intervals, which means, this service class receives data packets even if the network is in congestion mode. Usually this polling mechanism repeats on the interval of one or less second [3].

*E. Best Effort(BE)*

BE is used to provide services on the basis of best effort mechanism. Contention mechanism process has to be set for this service to work properly, as it is based on best effort, due to this, it might get less opportunities as compared to others. So a policy should be set by using which it get proper contention opportunities [14]. Table. 1 summarize the QoS classes briefly.

TABLE 1. WiMAX QoS Classes

| **QoS Class** | **Applications** | **QoS Specification** |
|---|---|---|
| Unsolicited Grant Service (UGS) | VoIP, E1/T1 | Jitter Tolerance<br>Maximum latency tolerance<br>Maximum sustained rate |
| real time Polling Service (rtPS) | Streaming Video and Audio | Maximum latency tolerance<br>Maximum sustained rate<br>Traffic Priority<br>Maximum reserved rate |
| extended real time Polling Service (ertPS) | VoIP with Silence Suppression | Maximum latency tolerance<br>Maximum sustained rate<br>Traffic Priority<br>Maximum reserved rate<br>Jitter Tolerance |
| non real time Polling Service (nrtPS) | FTP | Maximum sustained rate<br>Traffic Priority<br>Maximum reserved rate |
| Best Effort (BE) | Web Browsing, Data Transfer | Maximum sustained rate<br>Maximum reserved rate |

## 4. SCHEDULING ALGORITHMS

As networks data comprises of different data packets, which have to be recognized or differentiated according to their packet types. For this purpose, scheduling of data packets considered to be critical. Because, in other words, scheduling relates to the sharing of bandwidth resources. Initially, First In First Out (FIFO) was introduced, which has only one main queue, that collect all the packets and forward them in a sequence as they received. Due this equality or lacking of any scheduling, packets that have higher priority or urgent data, will observe delay and will not be delivered on time. However, after this, different scheduling techniques was introduced, that will discuss briefly in this section.

As scheduling algorithms perform critical role in band-width sharing and packet scheduling process, every algorithm should have some purpose or aim, on the basis of which it is used. First of all, used algorithm should have capability to share total amount of bandwidth in fair manner. Secondly, every SS in network should have minimum guaranteed bandwidth. Thirdly, should have capability to reduce variations in latency. All these purposes are helpful in provision of QoS.

*A. Priority Queue (PQ)*

In Priority Queue, initially packets are classified by using scheduler according to their class. After this, these classified packets moved into different queues according to their classes. PQ will serve the queue which has highest priority. Highest priority queue will be served until it gets empty. After this, second highest priority queue will be served. Due to this scheduling mechanism, bandwidth starvation will occur for low priority data traffics.

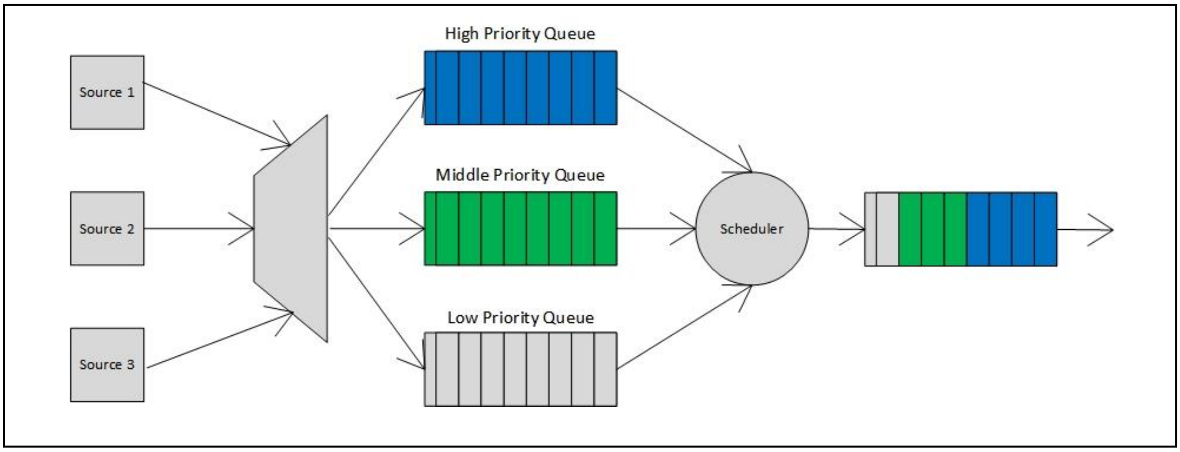


Figure. 2. PQ

*B. Weighted Fair Queue (WFQ)*

Weighted Fair Queue, specifically used to schedule packets of various sizes to provide prioritization in traffic management. WFQ serve every queue fairly by terms of byte count, which creates a bit wise fairness. It is usually used under conditions, where a consistent response time is required for heavy and light network users. Advantage of WFQ is that, queues does not starve for Bandwidth and any bandwidth that is not used by any flow, will be divided up among remaining flows [15] [16].

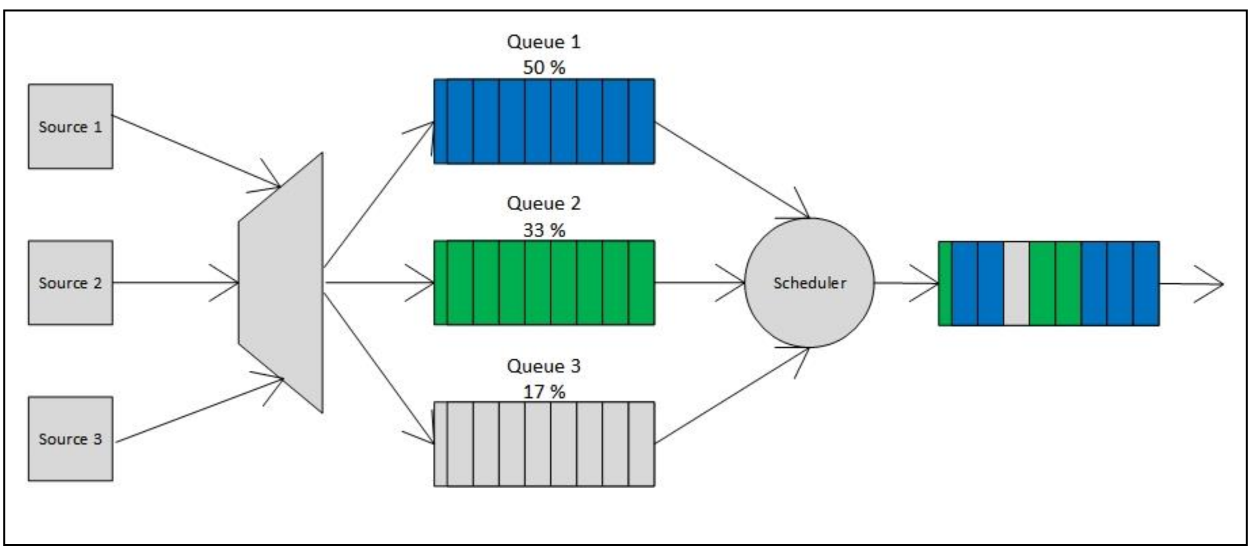


Figure. 3. WFQ

As WFQ scheduler, order packets from queue by using queue weights. For example, in Fig. 3, queue 1 gets 50% of the total bandwidth, queue 2 gets 33% and queue 3 gets 17% of the bandwidth resources, it means that queue 1 have the highest weight among all others.

*C. Deficit Round Robin (DRR)*

Deficit Round Robin (DRR) also known as Deficit Weighted Round Robin (DWRR). In [10] authors, designed an efficient fair queuing algorithm that was based on to overcome the issues of previous WRR and RR algorithms. In this DRR algorithm, each queue has a deficit counter that is initially set to quantum of queue. Whereas, quantum is the configurable value of credit given to a queue during its serving duration. This quantum value is in the form of bits/bytes and represents the credit of bits/bytes a queue may require. Usually it can say that, increasing the value of quantum directly relates (proportional) with the assigning weight to queue.

As in DRR, a specific quantum credit is assigned to each queue. If size of a packet at head of the queue exceeds to the size of queue quantum, remainder credit of quantum for that serving queue is added to the new quantum that will assign to this queue for next round. Similarly like quantum, remaining packets from queue are compensated in next round. At start of the process, all of the deficit counters have zero value and scheduler or pointer starts from the top of list. As shown in Fig. 4, first queue in the process that will serve, initially has quantum value of 1000 that will be added to Deficit Counter value. As, data in the queue is of 1500 bytes, so first 1000 bytes will be served in this round for queue 1 and remaining 500 bytes will be served in next round. Similarly for queue 2, it has 800 bytes of data to be transmitted, all data in this queue will be transmitted in current round and remaining 200 bytes of quantum value will be added in deficit for next round. Same process will be used in queue 3, which has a size of 1200 bytes. As figure shows that, in second round queue 2 has no data to send, due to this, its deficit value will be set to zero.

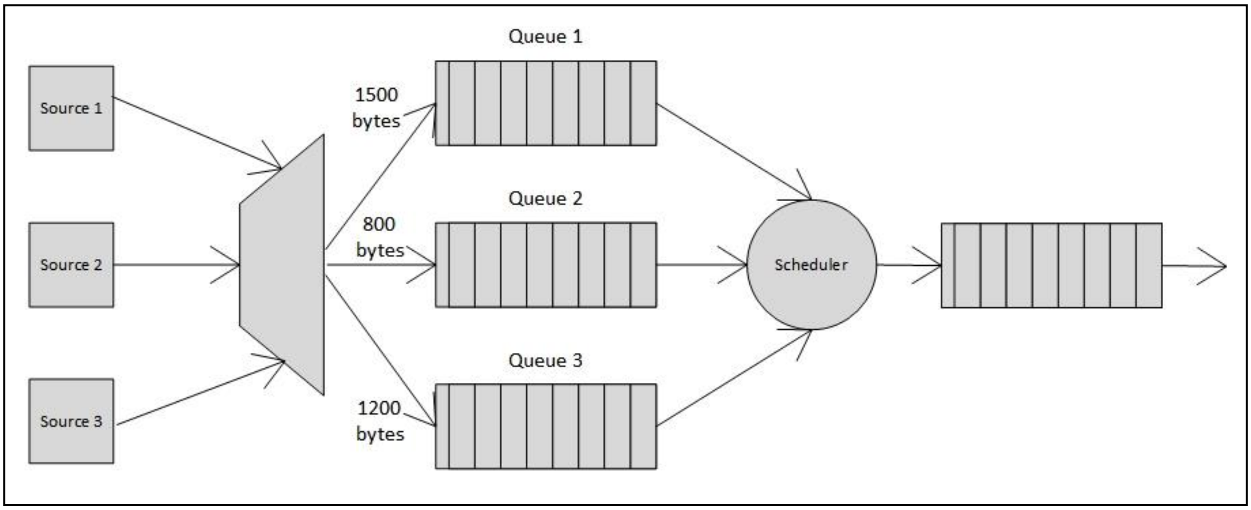


Figure. 4. DRR

*D. Modified Deficit Round Robin (MDRR)*

Modified Deficit Round Robin scheduling algorithm is an extension of the above mentioned DRR algorithm [17]. There are different modifications that were introduced in this algorithm, due to this, overall it is known as MDRR. As MDRR algorithm depends on DRR scheduling fundamental principles, however, in MDRR, quantum value given to the queues is based on weights associated with them. MDRR scheduling scheme adds a PQ into consideration with DRR. Purpose of Priority Queuing scheme is to isolates high demanding data or flows from other flows for better quality of service provisioning [18]. According to the mode of serving the Priority Queue, there are two types of MDRR schemes.

Alternate Mode: In this mode, high priority queue is served in between every other queue. For example, output sequence of packets from different queue will be like this, PQ, Q1, PQ, Q2, PQ, Q3, PQ, Q4 as shown in Fig. 5.

Strict Priority Mode: In this mode, high priority queue will be served first, after transmission of all packets from high priority queue other queues will serve.

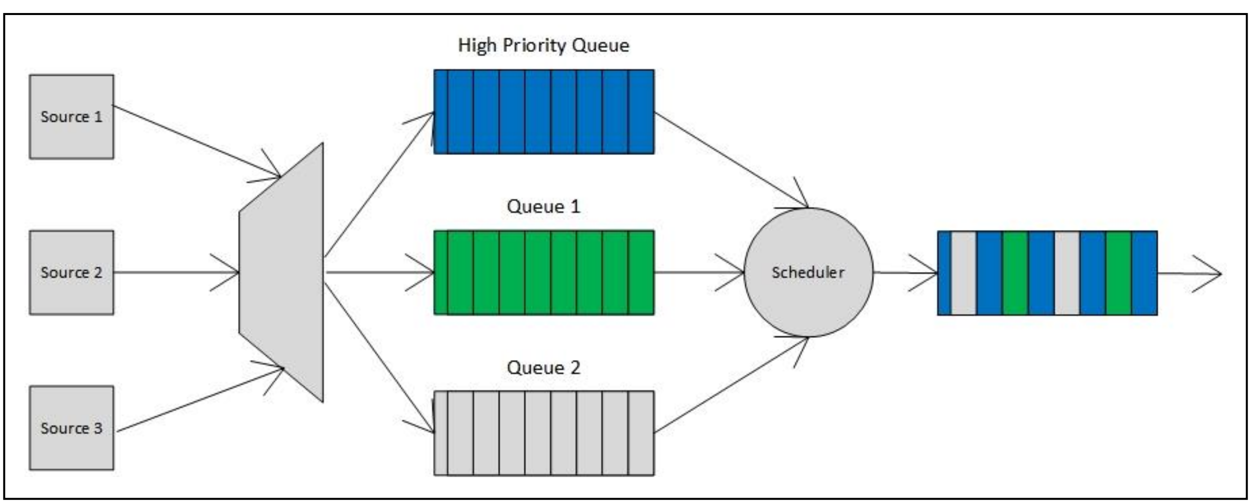


Figure. 5. MDRR

## 5. SIMULATION SETUP

Several scenarios has been considered for performance evaluation in WiMAX. For this purpose, OPNET simulator with WiMAX module is used. Different traffic type's e.g.,HyperText Transfer Protocol(HTTP), File Transfer Protocol

(FTP), Video and Voice over Internet Protocol (VoIP) applications with different data rates are consider, Table. 2 shows the simulation parameters used for simulations.

In this scenario, sixteen MS's deployed in the network, all these node are connected with a single BS. BS is connected with a server that has different types of data traffic (FTP, Heavy HTTP, Heavy Video and IP Telephony). For simplicity, each traffic types is deployed on four MS nodes. There are some priority metrics that are used to define the priority of a traffic type, Standard (2) is selected for HTTP, as it has low priority data and it can also bear delayed transmissions. Excellent Effort (3) is selected for FTP and for video, Streaming (4) priority type is selected, as selected video type has low resolution contents and for VoIP Interactive (6) type is selected, due to its real time operations. All these priorities has been selected to observe the behavior of scheduling algorithms in a better way.

TABLE 2. Simulation Parameters

| **Parameter Type** | **Parameter Value** |
|---|---|
| Base Frequency | 5 GHz |
| Bandwidth Oriented | 20 MHz |
| Duplexing Mode | TDD |
| System Bandwidth | 5 Mbps |
| Frame Duration | 5 ms |
| TTG | 106 ms |
| RTG | 60 ms |
| Phy | OFDMA |

## 6. SIMULATION RESULTS

Usually Subscriber Stations might have multiple simultaneous connections at the same time. Packets coming from higher layers are classified by Connection IDentifier (CID) according to QoS class types in CS sub-layer. As each class have separate queues, due to this, classified packets are queued in specific queues according to class type. These queues are stored in memory buffers. In following results we analyzed buffer utilization for each traffic type against scheduling algorithms. Whereas, Queuing Delay is the delay, experienced by packets in each queue measured in seconds. This delay depends on the individual queue size and data rate of the link. In other words, Queuing Delay is directly proportional to buffer size, which means, longer the line of packets queuing to be transmitted, longer the queuing delay is.

In Fig. 6, PQ is represented by green line and lied on zero scale, as HTTP is not able to transmit any sort of data due to low priority, means no data for transmission, that leads to-wards null buffer usage. Whereas, WFQ and MDRR has almost same level of utilization for HTTP and DWRR has high buffer utilization as compared to both other algorithms. In short, DWRR performs well and allow low priority traffic to take participation in communication process.

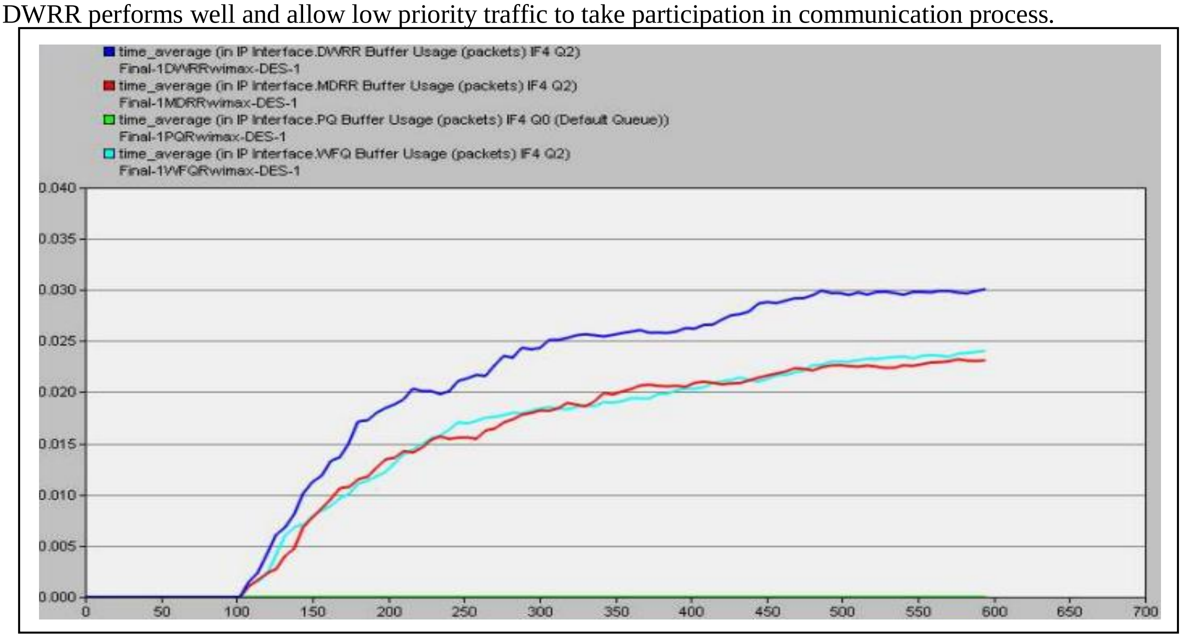


Figure. 6. Comparison of Buffer Utilization for HTTP

Fig. 7, shows buffer utilization for FTP, it is clear that PQ has highest buffer usage level because in PQ low priority traffic have fairness issues, due to this, incoming traffic remains in buffer most of the time until resources get free. Whereas, Video and VoIP has high priority and get resources very easily.

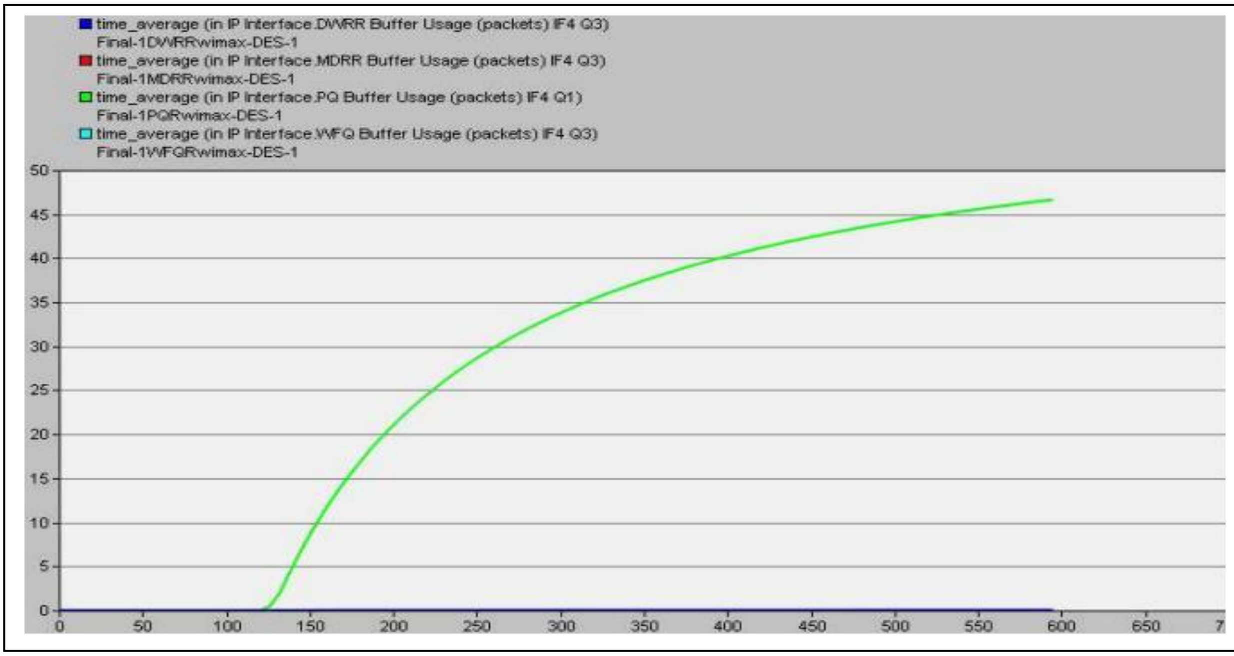


Figure. 7. Comparison of Buffer Utilization for FTP

Fig. 8, represents the buffer usage details for Video traffic, all algorithms except PQ have almost same level of buffer usage for video traffic however, PQ has very less utilization because of unfairness.

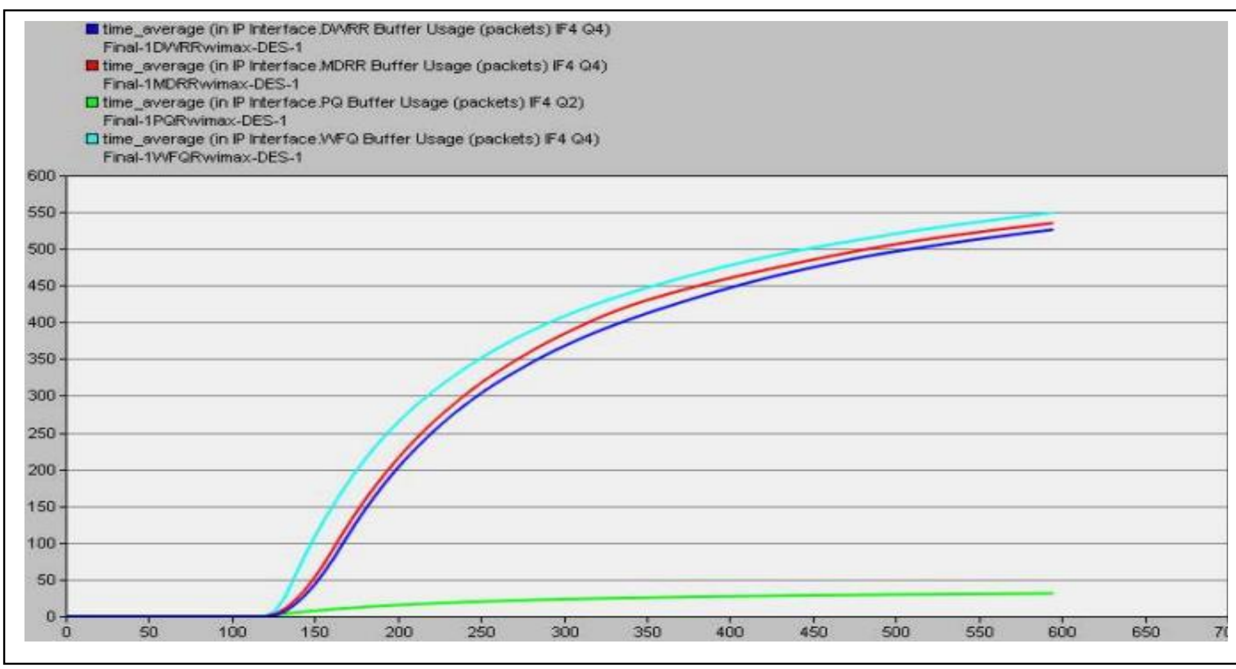


Figure. 8. Comparison of Buffer Utilization for Video

In Fig. 9, buffer utilization is shown for VoIP traffic, as VoIP has high priority so in all algorithms it deals in a good way however WFQ performs well in case of VoIP.

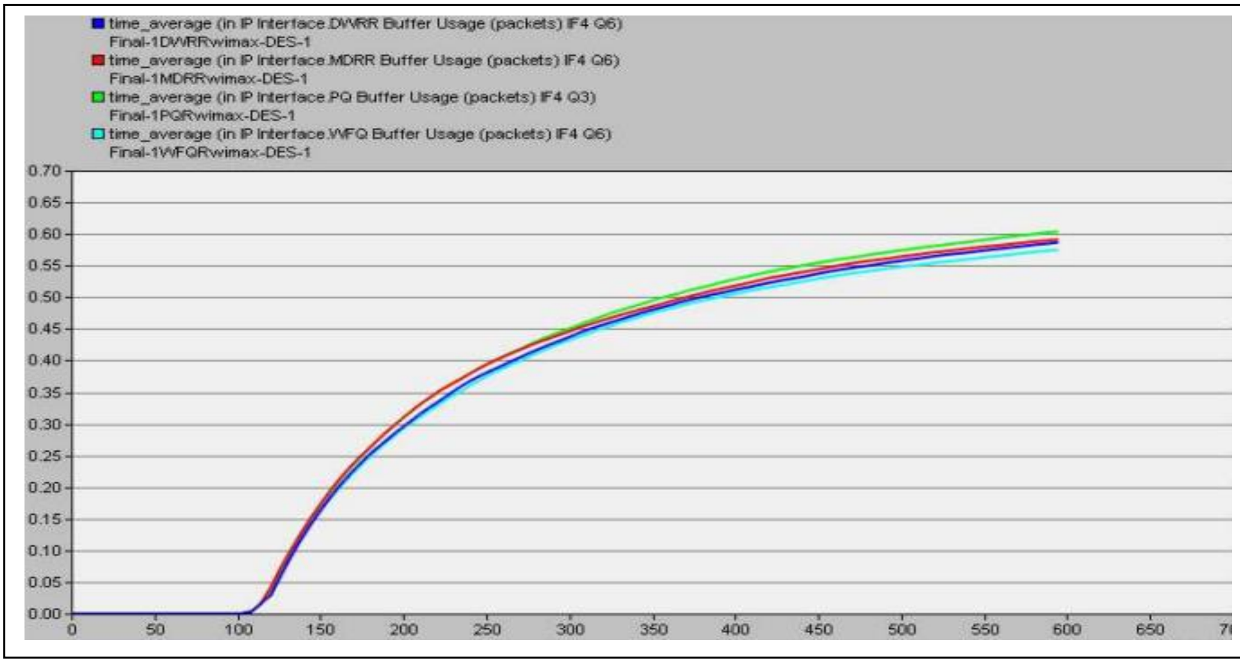


Figure. 9. Comparison of Buffer Utilization for VoIP

Fig. 10 shows the queuing delay for HTTP against different scheduling algorithms. As PQ does not able to get resources so no data traffic for PQ whereas, DWRR has an increased delay for HTTP traffic type as compared to MDRR and WFQ. MDRR performs best due to its compensation for low priority traffics.

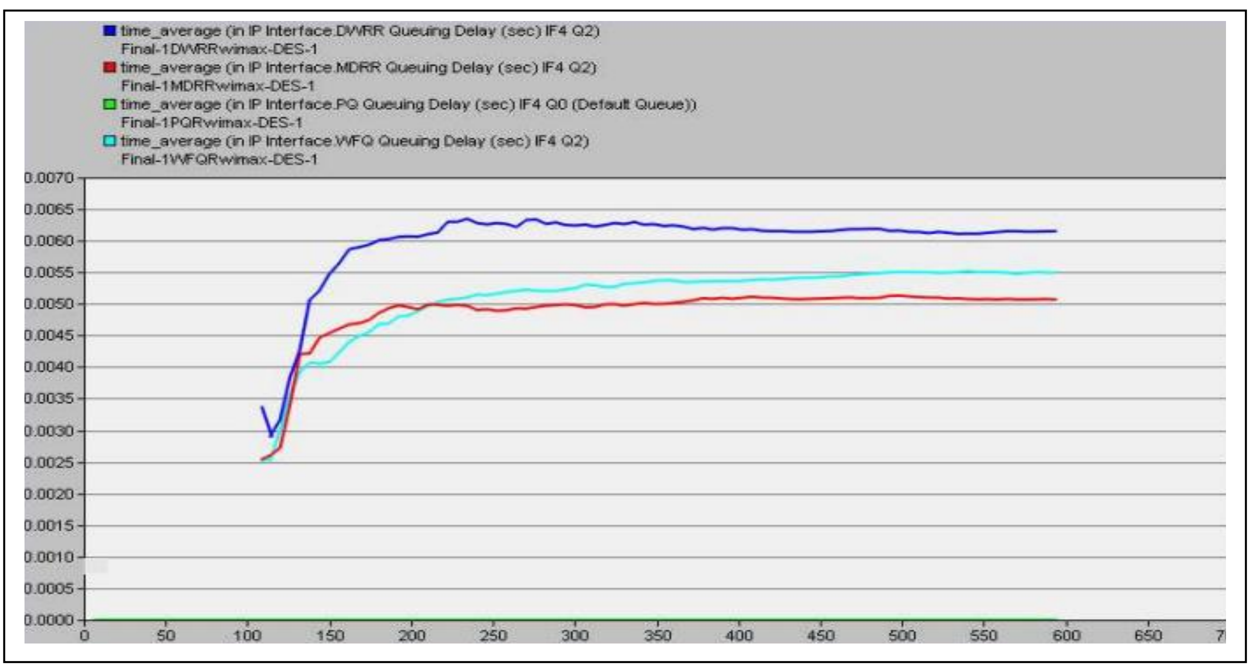


Figure. 10. Comparison of Queuing Delay for HTTP

In Fig. 11, after reception of data, PQ does not able to deal it and immediately moved into the buffer. Due to this delay will be observed throughout communication. Whereas, remaining algorithms have almost same level of queuing delay.

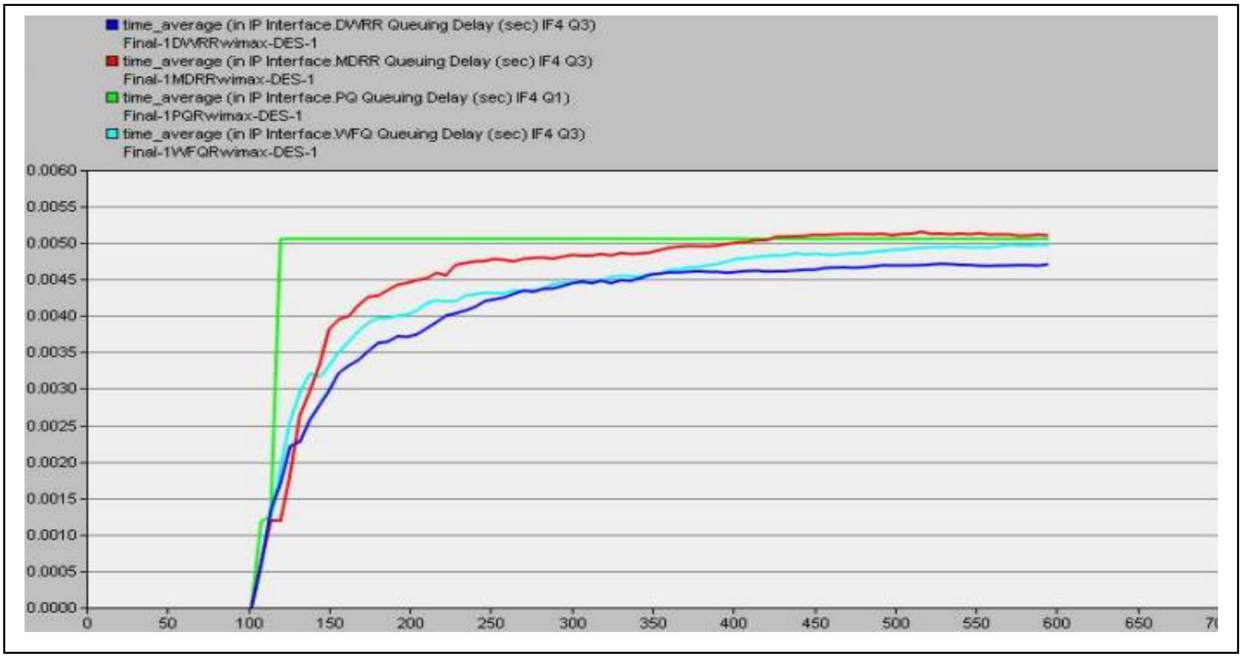


Figure. 11. Comparison of Queuing Delay for FTP

Fig. 12, shows the queuing delay for Video against scheduling algorithms. All have the same level of delay for Video except PQ, as PQ algorithm classify all packets according to traffic classes and high priority queues served until no more data remain in the queue to be transmit. Whereas, WFQ experience more delay as compared to others.

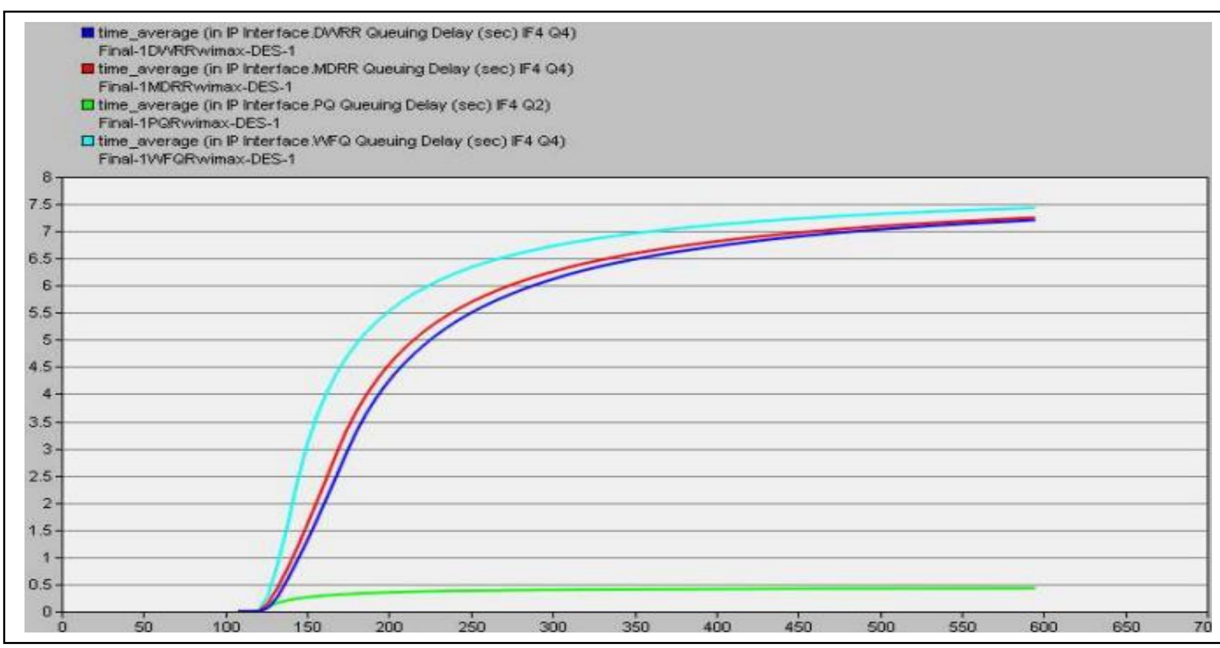


Figure. 12. Comparison of Queuing Delay for Video

Fig. 13, shows the queuing delay for VoIP against scheduling algorithms and all have the same level of delay for VoIP, because VoIP served by them as highest priority traffic. So in short, PQ performs best for High priority traffics but worst in case of low priority that create the issues of fairness. However, MDRR is consistent throughout all traffic types.

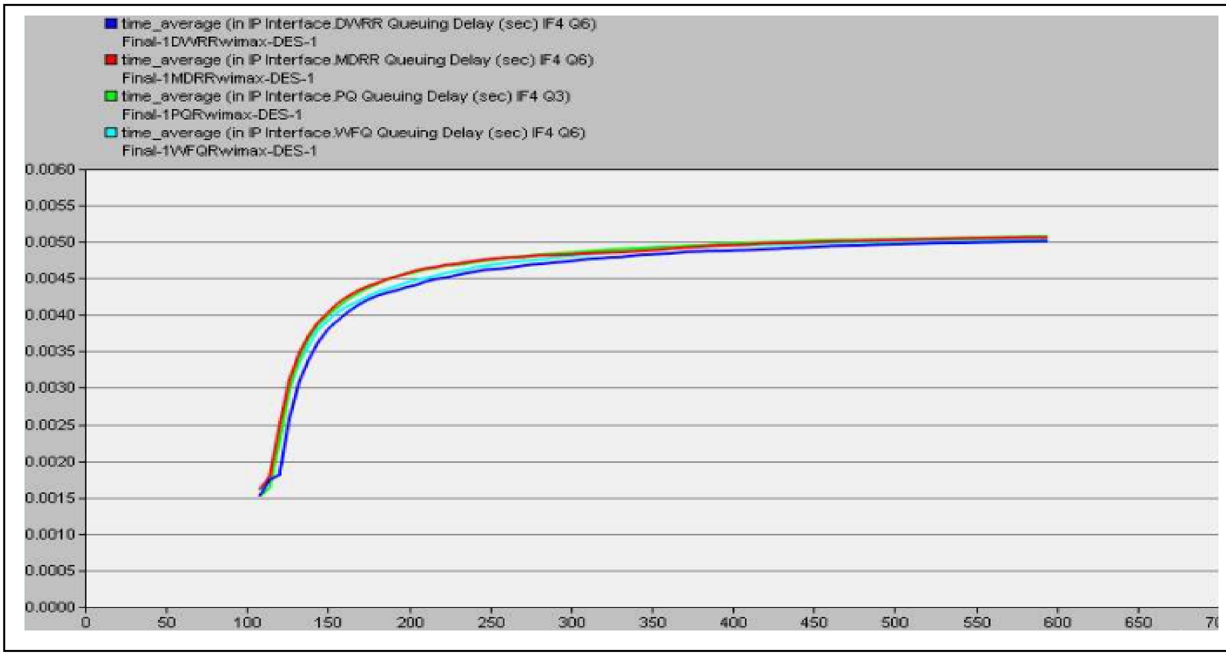


Figure. 13. Comparison of Queuing Delay for VoIP

## 7. CONCLUSION

Comparison of different scheduling algorithms (Weighted Fair Queue, Deficit Weighted Round Robin, Modified Deficit Round Robin and Priority Queue) has done in this work. Delay and buffer utilization was consider for evaluation, in simulation scenario a number of nodes was selected with different traffic types and then use scheduling algorithms to schedule bandwidth resources for the nodes. During these simulations above mentioned parameters was analyzed for performance. Results shows that MDRR algorithm performs better than others, However in some cases, e.g., in case of VoIP traffic, resources were not allocated properly, specifically if BE service was selected, in few cases it does not transmit even a small amount of data that leads towards the unfair bandwidth sharing, but overall MDRR performs better.

## REFERENCES

[1] IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems," IEEE Std 802.16-2001 , vol., no., pp.0_1,322, 2002
[2] IEEE Standard for Local and Metropolitan Area Networks --- Part 16: Air Interface for Fixed Broadband Wireless Access Systems--- Amendment 2: Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz," IEEE Std 802.16a-2003 (Amendment to IEEE Std 802.16-2001) , vol., no., pp.0_1,292, 2003
[3] IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems," IEEE Std 802.16-2004 (Revision of IEEE Std 802.16-2001) , vol., no., pp.0_1,857, 2004
[4] IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1," IEEE Std 802.16e-2005 and IEEE Std 802.16-2004/Cor 1-2005 (Amendment and Corrigendum to IEEE Std 802.16-2004) , vol., no., pp.0_1,822, 2006
[5] Siraj, Mohammad, and Kamalrulnizam Abu Bakar. "Link establishment and performance evaluation in IEEE 802.16 wireless mesh networks." Int. J. Phys. Sci 6.13 (2011): 3189-3197.
[6] Kas, Miray, et al. "A survey on scheduling in IEEE 802.16 mesh mode."Communications Surveys & Tutorials, IEEE 12.2 (2010): 205-221.
[7] Murawwat, Sadia, et al. "An Overview of Scheduling Strategies for PMP Mode in IEEE 802.16." Sci. Int. (Lahore) 24.3 (2012): 307-315.
[8] Cicconetti, Claudio, et al. "Performance evaluation of the IEEE 802.16 MAC for QoS support." Mobile Computing, IEEE Transactions on 6.1 (2007): 26-38.
[9] Singla, Saruchi, and Maninder Singh Kamboj. "Analysis of Packet Scheduling in WiMAX Network." International Conference on Recent Advances and Future Trends in Information Technology. 2012.
[10] Lin, Jin, and HarshaSirisena. "Quality of service scheduling in IEEE 802.16 broadband wireless networks." Industrial and Information Systems, First International Conference on. IEEE, 2006.

[11] Wongthavarawat, Kitti, and Aura Ganz. "Packet scheduling for QoS support in IEEE 802.16 broadband wireless access systems." International Journal of Communication Systems 16.1 (2003): 81-96.

[12] Nie, Wei, Houjun Wang, and Jong Hyuk Park. "Packet Scheduling with QoS and Fairness for Downlink Traffic in WiMAX Networks." JIPS 7.2 (2011): 261-270.

[13] Kumar, A., Garg, D. "Queuing Algorithm Based Quality of Service (QoS) For Scheduling Environment Model in WiMAX Network with Opnet Modeler." Global Journal of Researches in Engineering, 11.8 (2011): 35-40.

[14] Chou, Li-Der, Yen-Cheng Lin, and Zi-Hong Chen. "QoS coordinated distributed scheduling for 802.16 mesh networks." Internet, 2009. AH-ICI 2009. First Asian Himalayas International Conference on. IEEE, 2009.

[15] Chan, S., et al. "Algorithms for WiMAX scheduling." Microwave Conference, 2008. APMC 2008. Asia-Pacific. IEEE, 2008.

[16] Lin, Jin-Cherng, Chun-Lun Chou, and Cheng-Hsiung Liu. "Performance evaluation for scheduling algorithms in WiMAX network." Advanced Information Networking and Applications-Workshops, 2008. AINAW 2008. 22nd International Conference on. IEEE, 2008.

[17] Shreedhar, Madhavapeddi, and George Varghese. "Efficient fair queuing using deficit round-robin." Networking, IEEE/ACM Transactions on 4.3 (1996): 375-385.

**[18]** Ravichandiran, C., C. Pethuru Raj, and V. Vaidhyanathan. "Analysis, Modification, and Implementation (AMI) of Scheduling Algorithm for the IEEE 802.116 e (Mobile WiMAX)." arXiv preprint arXiv:1003.1479 (2010).


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