MFQMAC- A Faired and QoS Assured MAC protocol for Multihop Adhoc Network

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ABSTRACT

In this paper, a new protocol called MFQMAC is proposed, which has the following features. (i) It assures quality of service through service differentiation among different classes of traffics. (ii)It provides fairness among traffic flows of same priority class. It maintains fairness without decreasing the channel utilization and solves the unfairness problem between two communicating stations with same prioritized traffics. (iii) It is fully distributed and applicable not only to single hop but also for multi-hop environment. The performance of the protocol is evaluated from QoS as well as fairness point of view through extensive network simulator-2 simulation. It was found that, the protocol, MFQMAC assures high aggregate throughput and low end-to-end delay and jitter in comparison to other MAC protocols and hence said to have enhanced Quality of Service. Further, the protocol also have a better fairness index from IEEE 802.11 and FQA, which confirms its fairness assurance.

Keywords: MANET, Quality of Service, DCF, Fairness

1. INTRODUCTION

Mobile Adhoc Network (MANET) [1], [2] is a collection of mobile nodes with dynamic topology. Such networks are of interest because they do not require any prior investment in fixed infrastructure. Instead, the network nodes agree to relay each other's packets and hence act as routers and automatically form their own cooperative infrastructure. Wireless Adhoc Network provides lot of flexibility. At the same time, it comes with a whole of research challenges [4], [5]. Node mobility, bad quality of channel, scarcity of resources and many other problems are attracting the attention of the researchers over the last decade. These challenges are responsible for many problems that are still open issues, such as effective routing, effective medium access control (MAC) mechanisms, power management, mobility management etc. An ideal MAC protocol for Mobile Adhoc Network [3] should have the features of Quality of Service (QoS), fairness, power control etc. Recently, the issues of QoS provisioning and achieving fairness in Mobile Adhoc Networks (MANET) have been extensively studied. Most of the published works address QoS enhancement [6-13] & fairness assurance [15-16], [18] individually and very few work such as FQA [17] algorithm is available to achieve a balance between QoS and fairness. But FQA is implemented in AP of WLAN and hence not suitable for distributed Multihop Mobile Adhoc Network. In this paper, we have proposed a new protocol called MFQMAC which has the following features. (i) It assures quality of service through service differentiation among different classes of traffics. (ii)It provides fairness among traffic flows of same priority class. It maintains fairness without decreasing the channel utilization and solves the unfairness problem between two communicating stations with same prioritized traffics. (iii) It is fully distributed and applicable not only to single hop but also for multi-hop environment. This paper is structured as follows. Section 2 gives the explanation of the proposed MFQMAC protocol and Section 3 describes the simulation and results

2. THE PROPOSED MUTIHOP FAIRED QOS ASSURED MAC (MFQMAC) PROTOCOL

In this section, the detailed description of the protocol is given. Our protocol employs the IEEE 802.11[19] as a subroutine for channel contention. The proposed protocol called MFQMAC satisfies the following unique and desirable properties.

(i). MFQMAC assures quality of service through service differentiation among different classes of traffics.

(ii). MFQMAC provides fairness among traffic flows of same priority class. It maintains fairness without decreasing the channel utilization and solves the unfairness problem between two communicating stations with same prioritized traffics.

(iii). MFQMAC is fully distributed and applicable not only to single hop but also to multi-hop scenarios.

FQA [17] has also addressed the QoS and fairness similar to our proposed protocol but with the following differences.FQA is applicable to single hop infrastructure based Wireless Local Area Network and implemented in Access Point (AP).It cannot be applied to Mobile Adhoc Network. But our proposed protocol is applicable to distributed Mobile Adhoc Network and also has multi-hop capability.FQA provides node based fairness but our proposed protocol assures flow based fairness. That means fairness is assured for the same prioritized traffics. In our protocol, at the first level priority is assigned according to the traffic type and then fairness is assured at the second level. This is just reverse in FQA.

QoS Enhancement: QoS enhancement is one component of our proposed protocol MFQMAC. Fig.1 presents the detailed flow of the steps taken for achieving Quality of Service. It is assumed that the type of service that a packet will be receiving is marked in a packet header. It may be mentioned that the "DS" field in IPV4 and "TOS" field in IPV6 are used for the same purpose. In this work, we have considered three types of traffics: voice, video and datagram. This classification coincides with those of the access category of IEEE 802.11e and traffic type of 802.1D.In order to provide service differentiation to various types of traffic, different priority level is assigned. The priority level assigned to voice, video and data are 2(highest), 1 & 0(lowest) respectively. That means packets marked with voice will suffer minimal queuing delay and negligible packet loss rate followed by video and then datagram. To achieve this, voice traffic will contend the channel with lower contention window size and data traffic with highest window size. Typically, (CW_{min}, CW_{max}) have been taken as (7, 15), (15, 31) and (31, 1023) for priority class 2, 1 and 0 respectively. The window sizes considered here is just a typical example. The actual values may be varied according to the network & traffic density. If the traffic is of higher priority level, it will contend for the channel with a lower(CW_{min}, CW_{max}).

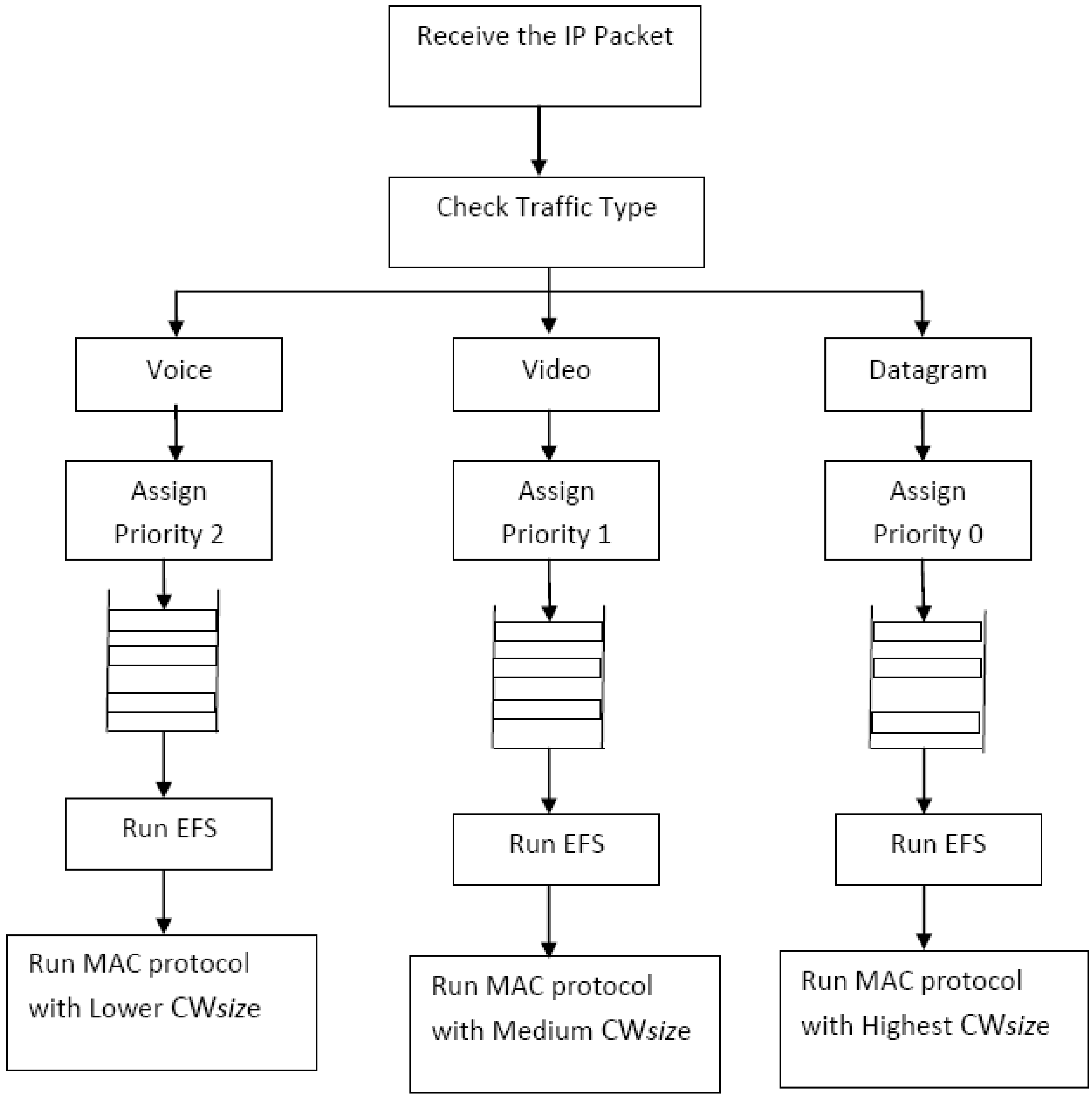

Figure.1: The MFQMAC procedure

Fairness Assurance: Another feature of our proposed MFQMAC protocol is to assure flow based fairness. The module EFS (Estimated Fair Service) in Figure.1 is used to achieve flow based fairness. The internal details of EFS are presented in the Figure.2.

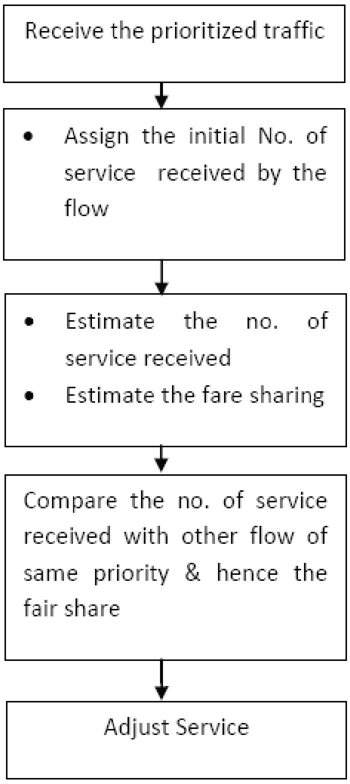

Figure.2.Estimated Fair Service (EFS)

In order to know the fairness service level of a particular flow of a said traffic class, we need to follow the procedure as given in Figure.2.When the network starts up, a flow of a particular traffic class is assigned an initialized and subsequently fairness value is estimated and compared. Accordingly, the service level is adjusted.

Procedure for estimating the fairness: Figure:3 shows a simple multi-hop scenario with four nodes A,B,C,D. Assuming node 'A' has some packets of different traffic class. It wants to send those packets to node 'D'.

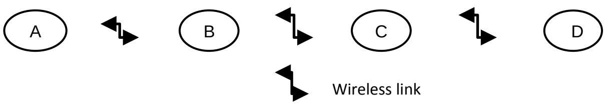

Figure: 3: Example of a Multihop Adhoc Network

Initially, on seeing the packets for the first time, we set, the serv_flow =1. Here serv_flow is the number of service obtained by a flow in the network. It is simply the number of packets of a particular flow that has reached the destination successfully. When the intermediate stations receive the packets of a new flow they set the serv_flow=1 with flow ID locally. After the packet finally reaches to the destination, the destination node will reply with an ACK for a particular flow-ID.. On receiving the ACK, the intermediate node increment serv_flow of the concerned flow by 1 and forward the ACK to the downstream nodes upto source node of the particular flow. Hence on sending the 1st packet of a particular flow successfully to the destination, all the nodes came across by the flow have set the serv_flow=2. In this way, every node keeps record of the services obtained by each flow generated and forwarded by it. When the packets of two different flows but of same priority have been enqued in IFQ (interface queue), the packet belonging to the minimum served flow is dequed.The node contends for the access of the channel with a contention window as follows.

$$\mathrm{CW} = \mathrm{scaling\_factor} * \mathrm{CW}^{\mathrm{i}} \quad --- (1)$$

$$\text{Here,} \quad \mathrm{scaling\_factor} = \mathrm{serv\_PF} / \mathrm{serv\_BSF}. \quad -- (2)$$

Where,

$\mathrm{serv}_{\mathrm{PF}}$
$=$ no. of serv. obtained by the flow currently seeking service.

$\mathrm{serv}_{\mathrm{BSF}}$
$=$ no. of serv. obtained by the better of the other flows of same priority class

CW^{i}
$=$ contention window corresponding to the priority class 'i'.

Hence station will reset the contention window for accessing the channel for the packets of a given flow with

$$\mathrm{CW}_{\mathrm{min}} = \mathrm{scaling}_{\mathrm{factor}} * \mathrm{CW}^{\mathrm{i}}_{\mathrm{min}} \quad --- (3)$$

$$\mathrm{CW}_{\mathrm{max}} = \mathrm{scaling}_{\mathrm{factor}} * \mathrm{CW}^{\mathrm{i}}_{\mathrm{max}} \quad --- (4)$$

It may be observed that scaling factor will be less than 1, when service obtained by the present flow is less than the other flows. Hence it will contend for the channel with still less contention windows.

Details of Enqueing & Dequeing Procedure: In the proposed, MFQMAC, queues are used to keep the incoming packets in a Queue. The interface dequeues the packet and initiates channel access. In a multi-hop scenario as in Fig.3, each node will maintain three queues q2, q1, q0 to enque the packets of different priority class 2, 1 and 0 respectively. After receiving the packet and knowing the type of traffic, they are enqued in their respective queues. As per the priority level, the queues are dequed. In our work the queue maintained for voice traffic that is q2 is attended first .then q2 and lastly q1.The procedures adopted are explained through the flow chart in Figure .4.

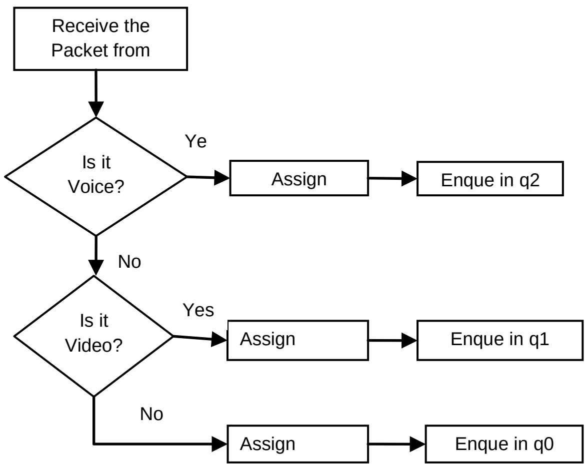

Figure: 4. Enqueuing procedure

The simple flow chart explaining the details of dequeues operation is presented in Figure: 5. At first, q2 the highest priority queue is checked and if it found to be non–empty, the packet is dequed.The contention window is set for that prioritized traffic, which is typically taken as (7, 15) in our work. Then CW_{size} is multiplied by the scaling factor. If the number of service obtained by the flow to which the packet belongs to, is less, compared to the minimum service among other flows, then the CW_{size} will be reduced and the node will contend for the channel with a less window size for the packet belonging to less served flow. If the service obtained by the concerned flow is more than the minimum served flow the contention window size will be set more. The operations are repeated until all the queues are empty.

Explanation of the protocol through an example: The protocol is explained by taking an example of a simple multihop adhoc network with different flows as shown in the Figure: 6

Assuming the node A generates voice, video and data packets which belong to the priority level 2, 1 and 0 in accordance with the proposed protocol. Let the individual flows be named as f_{A2} ,f_{A1} and f_{A0}.The packets are enqued in its own prioritized queue. Node 'B' generates voice packets belonging to the priority level 2 and let it be designated by flow ID f_{B2}. This node 'B' not only have to transmit from its own $f_{B2,}$ but also forward the packets of f_{A2} ,f_{A1} and f_{A0} .Node 'C' generates data packets which belongs to the priority level '0' and let the flow ID be set as f_{C0}. The node 'C' forwards the packets of flows f_{B2} , f_{A2} ,f_{A1} and f_{A0} also transmits the packets from it's own $f_{C0.}$ Initially all the flows f_{B2} , f_{A2} ,f_{A1} , f_{A0} and f_{C0} service obtained by the flow (serv_flow) equals to 1.That means , serv_ f_{B2} = 1, serv_ f_{A2} = 1, serv_ f_{A1} = 1 , serv_ f_{A0} = 1 and serv_ f_{C0} = 1. Let node 'A' simultaneously have voice, video and data packets to transmit. According to the rule the packets belonging to the priority 2 will be dequed and node 'A' will contend to access the channel with CWmin , CWmax belonging to the priority 2. If the node becomes successful in accessing the channel and send the packets which consequently reaches its intended destination 'D' then 'D' increment serv_ f_{A2} by 1 that is equal to 1. This information is piggybacked in the ACK packet and send to the downstream nodes (towards source).When node 'C' receives the ACK, it set serv_ f_{A2} =2; the node B and hence node A also set their serv_ f_{A2} =2 on receiving the ACK.

Now let us assume that node 'B' wants to transmit its own voice packets belonging to the flow f_{B2} at the same time node 'A' wants to transmit the packet belonging to f_{A2}. As serv_f_{A2} =2 and serv_f_{B2} = 1 at B, the packets belonging to the less served flow that is f_{B2} will be dequed.Node 'B' will contend for accessing the channel with contention window size with the scaling factor 0.5 where as node A

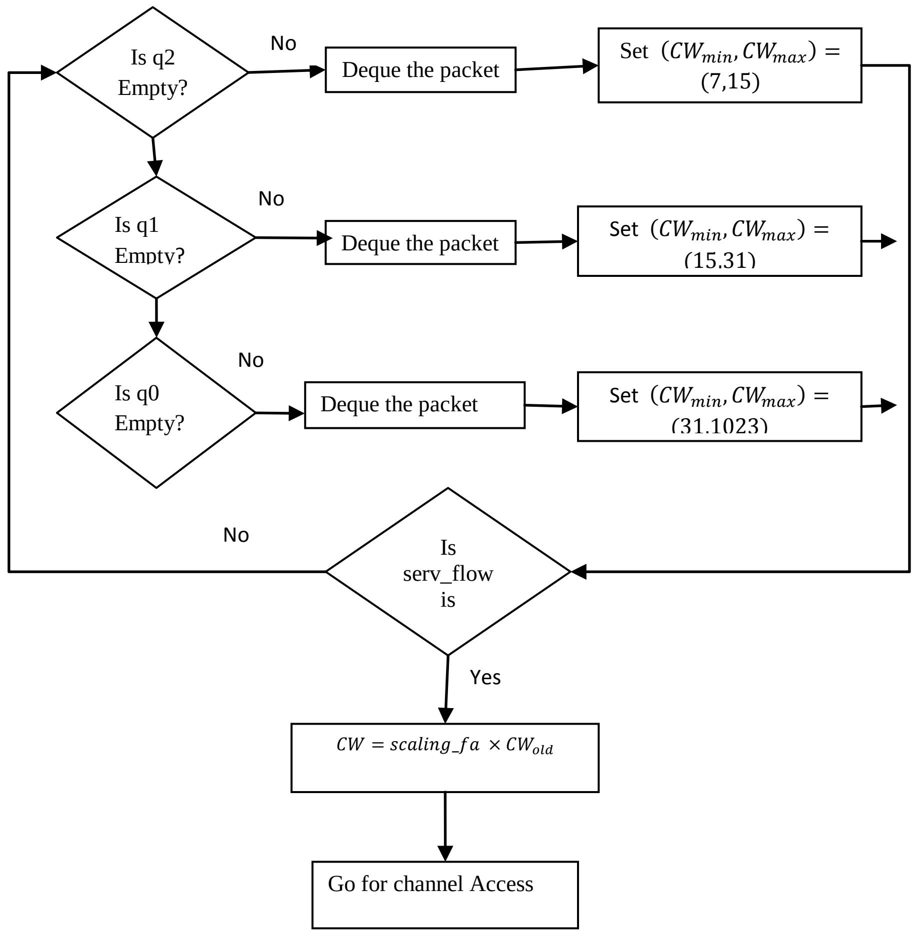

Figure: 5. Flow Chart for Dequeue Operation

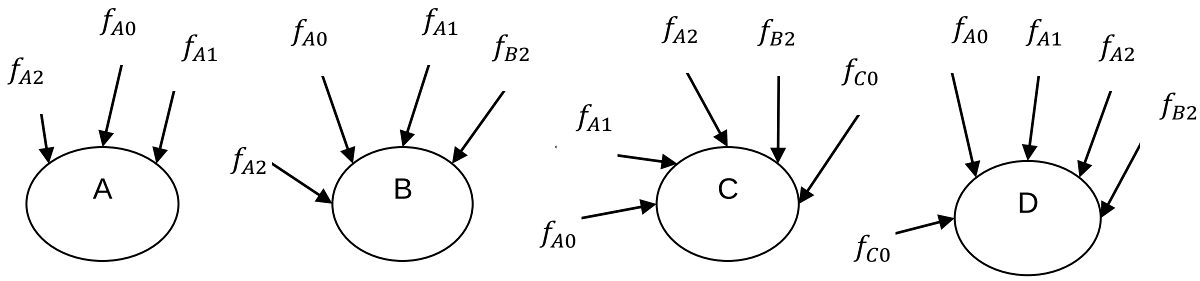

Figure: 6: Simple multihop scenario with different flows.

will contend with the scaling factor 1. That means the node B will contend for the channel with less sized window as compared to node A .Hence node B will be in a better position to access the channel. Hence the packets belonging to a less served flow such as serv_f_{B2} will be transmitted thereby showing the fairness.

3: SIMULATION WORK & RESULTS

Extensive simulation have been done using ns2.33 simulator [20] in order to evaluate the performance of the proposed MFQMAC protocol. The protocol has also been compared with other schemes such as DCF, AEDCF & FQA regarding QoS provisioning and per-flow fairness under various traffic scenarios. The Mobile Adhoc Networks were created with 6, 15, 21,25 nodes respectively confined to an area of 1000m by 1000m. The transmission range of a node was assumed as 250m. Initially, the nodes were randomly placed in the area. Each node remains stationary for a pause time, the duration of which follows an exponential distribution with a mean of 10 seconds. The node then chooses a random point in the area as its destination and starts to move towards it. The speed of the movement follows a uniform distribution between 0 and the maximal speed v_{max}. Network mobility is varied when we change *v*. Different network scenarios for v_{max}= 0, 5, 10 m/s are generated. The scenario v_{max} = 0 represents a static network with no link change. At *v* = 10 m/s, on average a node experiences a link change every 5 seconds. After reaching a destination, a node pauses again and starts to move towards another destination. This process is repeated for the duration of the simulation (250 seconds). The only constraint of the movement pattern is that it does not cause network partitions. Without network partition, there is always a route from a source to a destination, so no packet is dropped because the destination is unreachable. All dropped packets are due to network congestion or temporary route failure. Three different types of equivalence traffics such as audio, Video and datagram traffics were generated through CBR, VBR and FTP traffic sources. The DSR routing protocol is used for the purpose. ***Quality of Service (QoS) Evaluation of the proposed MAC protocol*** **:** The performance of our proposed MFQMAC protocol has been compared with others MAC protocols such as DCF, AEDCF & FQA in terms of *Transmission Delays, Aggregate Throughput, and Jitter* etc. These performance *metrics* were used for evaluating the protocol from QoS enhancement point of view. The effect of network density and hence the traffic density on the Aggregate Throughput is studied. Figure.7 shows the Aggregate throughput comparison for various MAC protocols as mentioned earlier. Here MFQMAC maintains highest aggregate throughput in comparison to others. When Number of nodes exceeds the value 20, the throughput of DCF and AEDCF decreases considerably due to high probability of collisions. The higher throughput obtained in MFQMAC is due to the strict queue management, the prioritization and contention with lower window size.

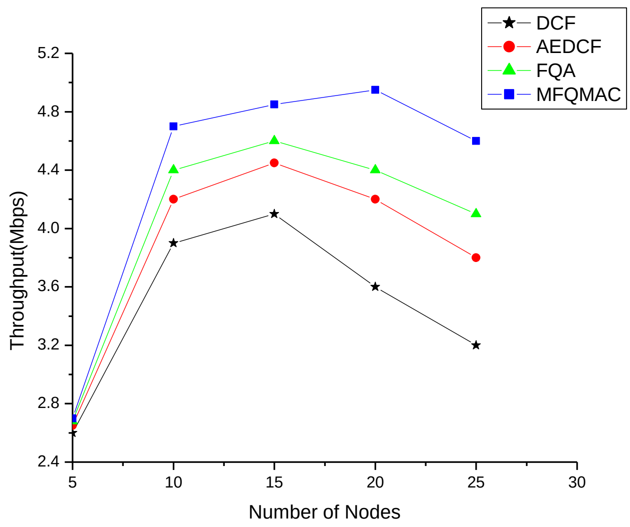

Figure.7: Aggregate Throughput

In DCF, one queue is maintained by the station which is FCFS type. The queue length varies from zero to maximum buffer size. Due to large delay variation, leads to increased delay jitter & and transmission delay. In MFQMAC three queues are maintained. Hence the variation in queue length is reduced and also the transmission delays and jitter are kept at minimum. The comparison on transmission delays and jitter are shown in the Figure 8 & Figure.9.

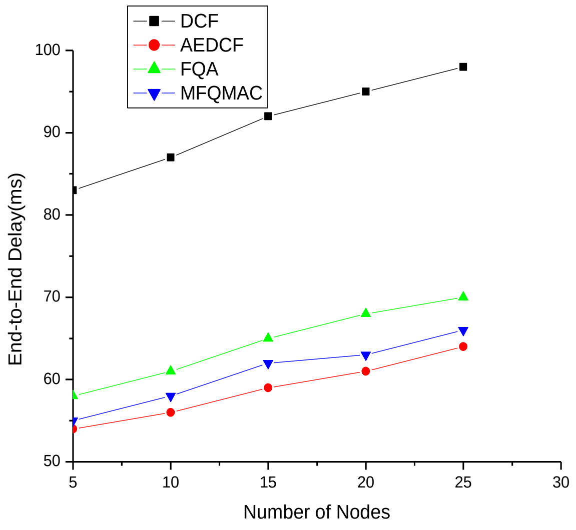

Figure.8: End-to-End Delay

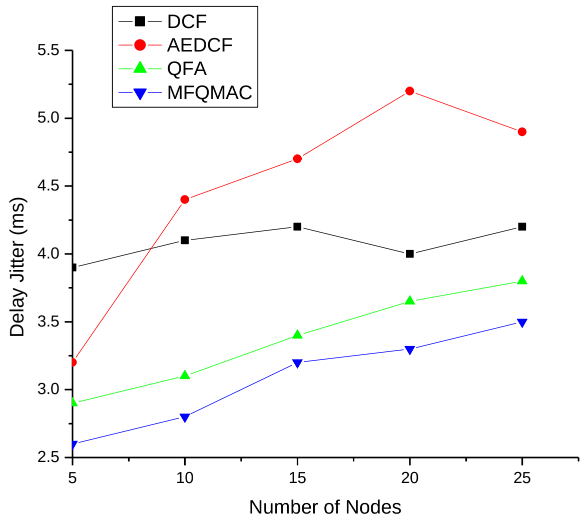

Figure.9: Delay Jitter

From the simulation results presented through Fig.7, Fig.8 & Fig.9, we have shown that our proposed MFQMAC protocol assures higher aggregate throughput .Further, it experiences less end-to-end delay and smaller values of delay jitter. Hence, our proposed protocol is said to have enhanced Quality of Service (QoS).

Fairness Evaluation of our proposed MAC protocol: Another very important constituent of our work is the ***fairness***. The well known Jain index [15] is used as the main performance metrics to define the level of fairness achieved by our protocol.

The Jain-Index is defined as

$$F_J = \left(\sum_{i=1}^{L} \eta_i\right)^2 / L.\left(\sum_{i=1}^{L} {\eta_i}^2\right) \quad - - - - - (\mathbf{5})$$

Where L is the total number of flows that share the wireless medium. And η_i is the fraction of the bandwidth utilized by the flow i over certain number of packets say m (window).Generally F_J (Jain-Index) value increases with m .Absolute fairness is achieved with $F_J = 1$ and unfairness is achieved for $F_J = 1/L$ .Here index is averaged over all sliding windows of ***m*** packets which occur in the simulation run.

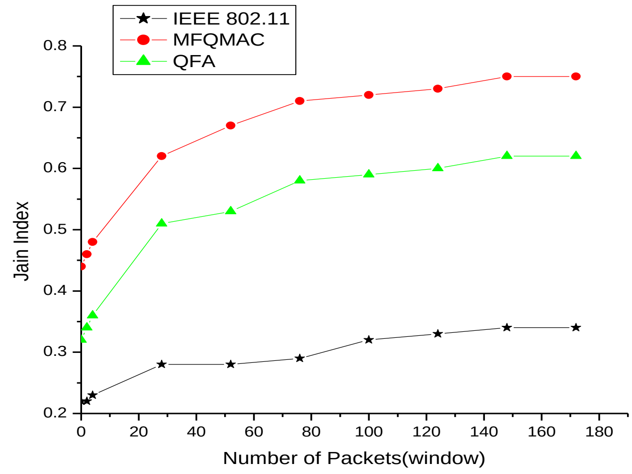

Figure .10: Performance Measure of Fairness

From the above results, it is obvious that our protocol is much fair to all flows and it totally outperforms the legacy 802.11 DCF.The proposed protocol achieves an average fairness index of around 0.72 where as the 802.11 achieves around 0.31 and for FQA, it is about 0.58.Hence, from the observation, it is clear that, our protocol not only provides quality of service but also achieves considerable amount of fairness among the multiple flows of the communicating nodes.

4. CONCLUSION

In this paper, a new medium access control protocol called MFQMAC is proposed for Mobile Adhoc Network. The protocol supports quality of service, exhibits fairness over multihop adhoc network. Aggregate Throughput and End-to-Delay and Delay Jitter experienced by different type of traffics were analyzed. The performance of the proposed protocol is compared with other MAC protocols, such as DCF, AEDCF & FQA through these three performance metrics. It was found that, the protocol, MFQMAC assures higher aggregate throughput and lower end-to-end delay and jitter in comparison to other MAC protocols and hence said to have enhanced Quality of Service. This feature was achieved due to strict queue management, prioritization and use of lower Contention Window Size.

The proposed protocol also assures fairness among the flows of same prioritized traffics besides enhancing QoS. Fairness is estimated for each flow, willing to access the channel. A new flow is allowed to access the channel earlier than an already served flow to achieve fair service among all the flows. We have also evaluated our proposed protocol (MFQMAC) from fairness point of view through the standard “Jain Index” as the performance metrics. We found that the Average Jain Index for our case is better than FQA and IEEE 802.11 protocol.

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