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A PRIORITY-BASED QUEUE MANAGEMENT APPROACH FOR AODV PROTOCOL TO SUPPORT QOS PROVISION FOR REAL -TIME APPLICATIONS IN MANET.

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Abstract— In this article, an enhancement is proposed in widely used Ad-hoc On-demand Distance Vector (AODV) routing protocol to deliver QoS provision for real-time applications in MANET. Whenever an activehop has no valid path to the intended target node, the AODV protocol buffers packets in a queue and begins its route discovery phase by disseminating route request (RREQ) queries. Conventional AODV routing protocol uses First-in-first-out (FIFO) or drop tail queue management policy to arrange the packets in its queue. We develop Priority-based queue management (PbQM) policy for real-time packets to satisfy its QoS constraints. The proposed queue management technique is implemented in basic AODV. This new variant of AODV routing protocol, called PbQM-AODV, which improve QoS in MANET. Extensive experiments are conducted to examine the performance of PbQM-AODV in the NS-2.34 simulator and compare its performance with the basic drop tail and Predictive Queue Management (PAQMAN) techniques. The experimental results reflect the performance improvements of the proposed approach in terms of packet delivery ratio (PDR), bandwidth and end-to-end delay.

***Keywords*—** AODV ; MANET ; priority ; QoS ; queue management;

I. INTRODUCTION

Recently, the advancements of communication technologies together with the proliferation of mobile computing devices have fetched revolution in wireless networks. One such significant class of network is called Mobile Ad hoc Networks (MANET). It is defined as a collection of self-organizing mobile nodes communicating without any fixed infrastructures or fixed base stations. The proficiency of quick deployment and the omnipresent access ability of MANET make them decisive in modern network applications. In MANET, delivering information between mobile nodes can be done directly by single-hop manner or indirectly by multiple-hop scenario via relay nodes (i.e. intermediate nodes). Therefore, every host in MANET serves not only as a transceiver but also as a router or gateway.

The increasing use of hard real-time applications needs stringent Quality of Service (QoS) guarantees which depends on many constraints like bandwidth, end-to-end delay, data drop ratio, jitter, network load, and energy. The establishment of QoS guarantees as required by applications through conventional routing protocols is a challenging endeavor in MANET due to its dynamic topology, lack of load balancing capabilities, limited power supply and a deficiency of unified authority. Hence it is essential to have an efficient routing algorithm to satisfy a set of QoS constraints in spite of network dynamics.

Whenever a node has no valid path to the intended target node, the AODV protocol buffers the packets in a queue and begins its route discovery phase by disseminating route request (RREQ) queries. Queues are not of unbounded length and they can overflow. Generally, the AODV routing protocol uses the first-in-first-out (FIFO) or the drop tail queue management scheme. Here, the packets as they arrive are enqueued at the tail of the queue and dequeued at the head. The buffer overflow occurs when a new packet arrives while the queue is full and hence can't be stored in the queue. In this situation, the packet is dropped irrespective of its importance. This packet drop can have adverse effects on the QoS, especially in real time applications. For instance, the packet dropped due to buffer overflow maybe a frame of the VoIP application. When such a packet is dropped, it will significantly affect the quality of the real-time service. Hence, it becomes necessary to manage the queue and intelligently drop the packets that are of low importance.

Existing buffer management algorithms in AODV are not efficient enough to deliver QoS for hard real-time packets in uncertain and dynamic environments, because these approaches assume that the network is deterministic and predefined decisions will be statically implemented during scheduling. Therefore, a management process is required to evade this issue. The major goal of this research is to propose an enhancement to the traditional AODV protocol for satisfying the QoS demands without compromising the system

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performance. The objective of this research work is to provide an enhancement in AODV to adapt priority based queue management techniques that deliver QoS assurances to real-time applications in MANET that necessitate strict timing requirements, throughput and packet delivery ratio. The priority-based queue management technique can also exclude the necessity for major modification in original AODV. This can then deliver persistent support to hard real-time applications by integrating the potential benefits of basic AODV with novel buffer management policy.

1.1 Overview of original AODV

The fundamental objective of this study is to enhance the QoS of real-time applications in MANET. For this purpose, the AODV routing protocol is considered that can support diverse real-time applications. Farkas et al. studied and validated four well-known ad-hoc routing protocols by means of some QoS extensions such as priority queueing, broken link discovery, timeouts and rate control policies [1]. According to the simulation results, they illustrated that the AODV outperforms all other protocols including DSR, OLSR, and DSDV. Hence, AODV is selected as the optimal routing protocol of choice for the work proposed in this thesis.

The conventional AODV is a source-initiated protocol which determines possible routes purely on an "as required basis". AODV protocol operates in the following phases: (i) Route Discovery and (ii) Route Maintenance [2]. It defines five different control messages for route discovery and maintenance: Route Request (RREQ), Route Reply (RREP), Route Reply Acknowledgment (RREP-ACK), Route Error (RERR) and HELLO [3], [4].

Whenever data packets need to be transferred from a source to a sought destination, the source starts its route discovery phase by flooding RREQ packages to its immediate adjacent nodes. These intermediate nodes further propagate the request message until it reaches the final destination. Every intermediate node either responds to the RREQ by directing the RREP message backward to the source of RREQ or relays the RREQ to its nearby nodes after incrementing the hop count as presented in Figure 1.

AODV exploits the sequence numbers for all packets to decide whether the routing information is "sufficiently current" and to ensure loop-free routing [5]. As a source node issues RREQ messages to other nodes, a reverse route is automatically generated. While the route reply packet transverses backward to the source, every single node which lies on the route generates a forward pointer to the source of RREP package, updates its route-timeout information and registers the latest destination sequence number for the sought destination [2], [6].

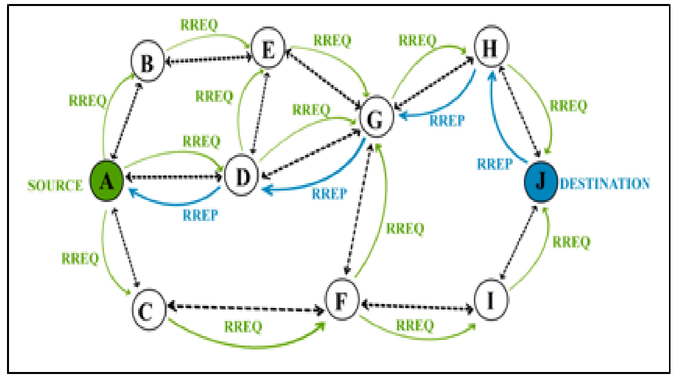

Figure 1: Route discovery of AODV

The established viable route is preserved as long as it is required by the source. Figure 1 shows a route discovery processas the initiative of the node A and toward node J. Using flooding source node A broadcast RREQ message to all its adjacent nodes. When J receives the RREQ, it returns a RREP message to A through H, G, and D.

The RERR message is created to inform other nodes about the route failure. It specifies those destinations which are no longer accessible through the failed link. To facilitate this reporting technique, every node maintains a "precursor list", comprising the Internet Protocol address (IP address) for all its nearby nodes that are used as the next hop for each destination [2], [6]. Optionally, the source node of the RREQ message forwards RREP-ACK package to acknowledge the route reply message [2]. HELLO packets can be utilized periodically to assure symmetric links and to identify the link breakages.

Generally, the AODV routing protocol uses the FIFO or the drop tail queue management scheme. Here, the packets as they arrive are enqueued at the tail of the queue and dequeued at the head. The buffer overflow occurs when a new packet arrives while the queue is full and hence can't be stored in the queue. In this situation, the packet is dropped irrespective of its importance. This packet drop can have adverse effects on the QoS, especially in real-time applications. For instance, the packet dropped due to buffer overflow maybe a frame of the VoIP application. When such a packet is dropped, it will significantly affect the quality of the real-time service. Hence, it becomes necessary to manage the queue and intelligently drop the packets that are of low importance.

1.2 Existing AODV Enhancements

Maamar et al. propose a modified variant to conventional AODV (M-AODV) protocol to enhance the QoS in MANET, which exploits an adaptive multipath concept for providing improved packet delivery ratio [7]. When there is a link failure, the source node selects alternative routes for packet propagation. Hence, M-AODV can significantly lessen the packet drop ratio by means of alternative paths for all source-destination pairs against link failure or node failure.

Another extension to AODV protocol is proposed by Boshoff and Helberg, called Delay Aware AODV-Multipath (DAAM) [8]. The proposed DAAM algorithm selects the route based on packet latency rather than the number of hops. Multiple backup paths along with the latency for every route are gathered in the routing table. If there is a path failure, the algorithm determines a new alternate path to the final destination before a new route acquisition process is started. Hence, DAAM offers a considerable reduction in packet latency, jitter and routing overhead.

Shayesteh and Khatereh develop a novel QoS routing algorithm, namely QoS AODV (QAODV), which considers parameters including the speed of the nodes, bandwidth, the RADIO-RX-SENSITIVITY, the RADIO-ANTENNAGAIN, battery power, and PROPAGATION-LIMIT along with the hop count used by conventional AODV protocol [9]. The proposed algorithm calculates the reliability of a viable path by combining all the seven metrics with weighing factors. Simulation results revealed that the proposed algorithm enhances performance measures such as PDR, end-to-end latency and the fault tolerance of the network considerably.

Jiazi Yi et al. investigate the effect of jitter in the route discovery procedure of AODV. They develop a modified jitter distribution, called window jitter, which considers the quality of communication links to estimate the jitter before retransmission of RREQ by intermediate nodes [10]. So control messages are propagated quicker over optimal routes. Experimental results indicate that the utilization of window jitter improves the performance of the route acquisition process of AODV and overcomes the disadvantages recognized for “naive” jitter.

Sharma et al. propose weight hop based packet scheduling technique for AODV, in which the intermediate node initiates the packet scheduling and handles its buffer memory based on the data transfer rate [11]. In this technique, data packets with fewer hop count to reach their destinations are granted higher weight. If there is a loss of link connectivity, the relay node buffers the data packets and recovers the failure route. This modified AODV protocol tries to transfer the data packet through alternative paths instead of discarding it.

Pradeep Macharla et al. develop a delay-based AODV protocol (AODV-D) to guarantee that delay does not surpass a maximum threshold value [12]. In addition to minimum hops, AODV-D will consider the channel contention statistics and amount of packets buffered in the interface queue (Ifq). From simulation studies, they demonstrate that AODV-D outperforms original AODV under average mobility and traffic load.

The reminder section of the article is organized as follows: We discuss some prior investigations which match our analysis in Section II.We discuss the fundamental concepts of priority-based queue management approach in section III. The implementation and evaluation details of PbQM in AODV protocol and are given Section IV. Then, we present our conclusion in section VIII.

II. RELATED WORK

The buffer management strategy is essential to manage the queue efficiently. These schemes can be classified into two types: Active Queue Management (AQM) and Passive Queue Management (PQM). In PQM method, an Internet router usuallypreservesa set of interface queues that keep packets scheduled to go out. These queues implement a drop-tail policy i.e. a packet is enqueued into the queue if its length is shorter than its maximum length (calculated in terms ofbytes or packets), and otherwise, it is discarded. PQM does not useprotective packet drop before the router queuebecomes full.AQM is a method that enables to discard packets before a buffer is filled. Normally, they work by preserving one or more drop/mark possibilities even when the queue is short. In this technique, the transmitting node is informed before it is near to be completelyoccupied so that the transmitter can halt data transmission or decrease the data rate. In the meantime, the present size of the buffer is reduced with the de-queuing and processing of buffered packets. Once anadequateroom is again available in the buffer, the transmitter can be permitted to transmit more packets for buffering in the queue and for further processing [13]. There are three rudimentary policies for discarding packets when a buffer is full are:

- **Drop Tail :** This mechanism defines a maximum sizeofthe queue at the router. The data packets are not classified in this policy. All the packetshaveequal priority. It implementsthe FIFO algorithm for

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transmitting packets. The router receives and transfers all the packets that arrive as long as its queue space is available for the arriving packets. When a packet reaches and the queue is full, the receiving packet will be discarded. The source finallydiscovers the data loss and contracts its sending window [14]. Drop Tail strategy will keep dropping the packet until the queue has sufficientspace for new packets. There are only two dropping possibilities in this scheme. If the number of packets received to the buffer larger than the predefined buffer size, discarding probability of packet is 1. Otherwise, the discarding probability is 0 [15].

- **Drop Front :** In this technique, traffic is not distinguished. Similar to Drop Tail scheme, every packet has the same priority. The router admits and transfers all the arrived packets as long as its queue size is available for the incoming packets. If a packet arrives and the queue is full, it discards the foremostone in the buffer.
- **Random Drop :** It drops anarbitrarily selected packet within a queue.

One of the most renowned AQM algorithms is Random Early Detection (RED) [16]. It discovers early congestion by calculating the average queue length. If the average queue length outdoes a predefinedvalue, RED marks incoming packets with a probability that is employed to decide what packets to drop. Some earlier researches presented the complications of selecting the RED parameters [17], [18]. Other investigations presented that there is no important benefit to RED over drop tail for web traffic [17]. Those disadvantages are the majormotives to default disable of the RED utility (or some manufacturer specific variant of RED, e. g., Cisco's Weighted RED (WRED) [19]) in most of the existing routers currently. To devastate these limitations, enhancements to the RED algorithm had been projected to make it more reliable and flexible, for instance, Stabilized RED (SRED) [20], Flow RED (FRED) [21], Dynamic RED (DRED) [22] etc. The most popular dynamic configured RED is the Adaptive RED (ARED) algorithm suggested by Floyed et al. In ARED, the maximum queue size is selected dynamically to preserve the average queue length within a target range [23].

III. PRIORITY-BASED QUEUE MANAGEMENT (PBQM)

Based on the drawback discussed earlier the FIFO/drop tail queuing scheme, we have designed a priority-based queue management. The purpose is to improve the QoS of the network by dropping the packets based on their importance (i.e., priority). Based on the PbQM, each packet is given a priority, indicating its importance. There are four different packet priorities (P1, P2, P3, and P4) used in this work.

IP based packet traffic classification method is used in this work. Packets from typical delay-sensitive applications such as Voice over IP, Video Conferencing, Video Broadcasting, Audio Broadcasting and Internet Relay Chat having a delay less than or equal to 200msec, are marked as High priority (P1) packets.All data packets from Telnet, Telemetry, Web browsing and AODV control packets having a delay in the range of 200msec to 400msec are marked as Medium priority (P2) packets. Packets from applications such as File Transfer Protocol (FTP) and e-mail having a delay in seconds are marked as Low priority (P3) packets. All other non-real time packets which have no specific requirements are marked as Best Effort (P4) packets. PBQM guarantees some sort of criteria for discarding packets that are of lower priority before discarding high priority packets.

<u>Algorithm .1PbQM – On overloading of Queue</u>

```
1:  for every new packet ri do
2:  find the priority of the incoming packet
2:  calculate the current length of the queue
    (q_current)
3:  if (q_current>= 95% of actual queue)
4:  drop the incoming packet ri if (Pi=4 or Pi=3or
     Pi=2)
5:   else
6:   if (q_current>= 85% of actual queue)
7:   drop the incoming packet ri if (Pi=4 or Pi=3)
8:   else
9:    if (q_current>= 75% of actual queue)
10:  drop the incoming packet ri if (Pi=4)
11:  else
 12: enqueue the packet
13:  end if
14:  end if
15:  end if
17:  end for
```

If the current queue length is >= 75% of the total queue size; the incoming packet with priority P4 is dropped (Line 10).If the current queue length is >= 85% of the total queue size, the incoming packet with priority P3 or P4 is dropped (Line 7). If the current queue length is >=95% of the total queue size, the incoming packet with priority P4 or P3 or P2 is dropped (Line 4). All of the dropped packets will be the packets with low priorities.

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IV. IMPLEMENTATION OF PBQM IN AODV ROUTING PROTOCOL

The performance of priority based buffer management scheme is evaluated and compared with tail drop buffer management and an active queue management scheme using AODV routing scenarios simulated in NS-2.34 in terms of packet loss ratio, transmission latency, and average throughput.

The AQM scheme selected to be compared with the proposed priority based buffer management scheme is ECN enabled Predictive Queue Management (PAQMAN) technique [24]. PAQMAN predicts the queue length in the next prediction interval in terms of the average of queue lengths estimated in sampling intervals within the current prediction interval. But, the prediction may not be precise because an opportunity always exists that there can be a major difference in numbers of packets received in two successive intervals. In this case, the packet loss possibility may contribute unexpected results by discarding higher numbers of packets or the inefficient utilization of resources. The responsiveness of PAQMAN is highly dependent on the value of the prediction interval. For shorter intervals, this technique is more responsive but increases the processing overhead [24], [25]. On the other hand, the responsiveness of the proposed technique operates with the current buffer utilization and the algorithm triggers when a sender reaches its assigned upper limit of buffer space and recalculates buffer space allocations for neighbors.

4.1 Simulation Environment

Three queue management algorithms are simulated using the same parameter value and packets are classified into four priorities according to their QoS demands. The packets from applications including VoIP, Video Broadcasting, Web browsing, FTP and e-mail are considered. A radio network of grid size 1500m x 1500m with each node assumed with mobility speed of minimum 2m/s and maximum 10m/s are considered for simulation. The number of data files a user receives during a session is geometrically distributed with mean 10.

VoIP and Video Broadcasting packets are assigned with class P1 (higher) priority. Since users tolerate greater delays when downloading World Wide Web (WWW) files or web pages, the data from Web browsing is assigned as a priority of class P2 (Medium priority). File Transfer Protocol (FTP) files are assigned with class P3, the low priority. Non real-time packets are assigned with class P4, best effort packets. The distribution of e-mail file sizes is approximated by a clipped Cauchy with mean 4 kB. WWW file sizes are log-normally distributed with mean 4.1 kB and standard deviation 44 kB. FTP files are assumed to be exponentially distributed. Data file inter-arrival times are Pareto distributed with mean 10 s.

Several mobility models for MANETs have been proposed recently. The Random WayPoint (RWP) model [26] is most widely used to describe the traffic behavior of the node. In the RWP model, a node selects arbitrarily a location in the simulated area and travels directly towards the destination at a uniform speed. If the node arrives at the destination it pauses for some time and then randomly selects a new position. The RWP model, however, has some severe issues as well. It does not consider groups of nodes and models every node autonomously of all other nodes.

Moreover, the direct node movement towards the destination is not very realistic, for example, inside buildings or when modeling vehicular nodes. Furthermore, the density of nodes in the center of the simulated area is much higher than at the borders [27]. Along with the mobility model, a traffic model is required to describe the traffic behavior of applied applications. In this case, typical traffic of real-time and streaming applications make use of small UDP packets, while non-real time applications use TCP packets that are exchanged between the nodes during communication.

4.2 Performance Metrics

To evaluate the performance of the PbQM against basic Drop Tail and PAQMAN, the following QoS metrics are utilized.

1. Average throughput :

Average throughput is the number of bits arrived at the intended destination successfully in the given time. It is calculated in Kbps.

$$\text{Average Throughput} = \frac{\sum(\text{Number of bits received})}{\sum(\text{Transmission Time})} \quad (1)$$

2. Average end-to-end delay :

For hard real-time applications, end-to-end transmission delay or latency is considered as a primary concern used to evaluate the performance. The latency of the packet is the mean time required to achieve its end-to-end transmission (from a source to the required destination). The lesser value of ED reflects the enhanced performance of the protocol. In this case, queueing delay of the real time packet is reduced significantly, which in turn reduces the overall transmission delay. ED is calculated in milliseconds using the following equation (2),

$$ED = \frac{\sum(\text{Arrival Time} - \text{Release Time})}{\sum \text{Number of connection}} \quad (2)$$

3. Packet delivery Ratio :

The fraction of the number of packets reached at the destinations divided by the number of packets transmitted from a source node is called as PDR. It is a significant parameter as it reflects the drop rate of the packets, which will further influence the maximum bandwidth of the network. The following equation is used to calculate this ratio.

$$PDR = \frac{\text{Number of received packets}}{\text{Number of transmitted packets}} \quad (3)$$

4.3 Scenario 1: Effect of Node density

The performance of the proposed scheme is compared with Drop Tail queue management and PAQMAN with AODV routing scenarios created in the simulator in terms of packet delivery ratios. For evaluation purpose, a MANET with different node density scenarios are is considered in a hybrid application environment. The buffer space in each node is configured as 64 packets and a Poisson distribution model is considered as the network traffic model. First, a MANET with the size of 20-node is configured to evaluate the packet delivery ratio of the studied schemes. Then the number of nodes is increased and tested for three more scenarios with 30, 40 and 50 nodes to check the performance of the proposed scheme in light as well as dense environments of congestion. Different data rates have been selected to study the performance of queue management schemes.

The packet delivery ratio is first obtained in a 20-node network scenario for different flow arrival rates mentioned in Figure2. The results indicate that the proposed PbQM technique performs better in terms of packet delivery ratio as compared to Drop Tail and PAQMAN techniques for various flow arrival rates. On the flow arrival rate of 20 Mbps, it is observed that the Drop Tail technique is marginally better than PAQMAN which specifies that Drop Tail outperforms PAQMAN in low traffic density scenarios. If the flow arrival rate increases, there are more probabilities of congestion due to more packet transmissions. Hence, the packet delivery ratio in all techniques generally decreases with the increase in packet arrival rate.

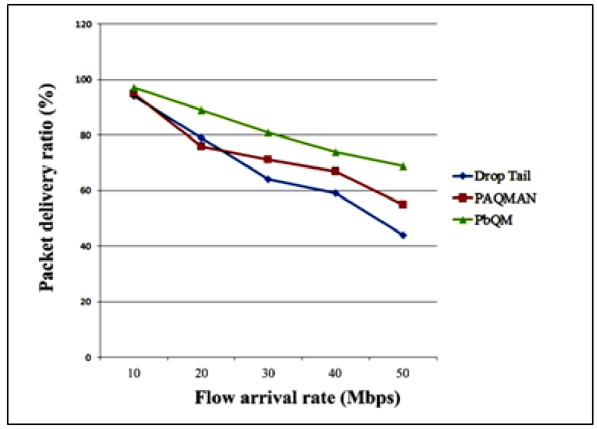

Figure 2: Packet delivery ratios for the network size of 20-nodes

Then the network size is increased by increasing the number of nodes to 30, 40 and 50 nodes. The same analysis is made to evaluate the performance of proposed PbQM technique. The simulation illustrates that the proposed technique remains better in terms of packet delivery ratio as compared to the other two schemes for different flow rates. The corresponding results are presented in Figures 3and 4.

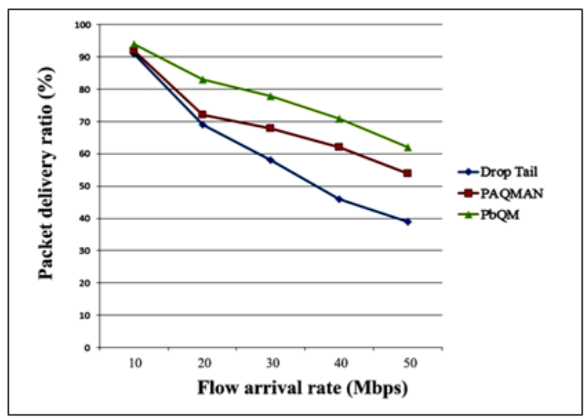

Figure 3: Packet delivery ratio for the network size of 30-nodes

In a 30-node network configuration, the average PDR of Drop Tail Scheme is 60.6%. The PAQMAN achieves 69.6%. The proposed scheme outperforms by achieving 77.6% mean PDR. For 40-node network size, the average PDR of Drop Tail Scheme is 56.8%. The PAQMAN achieves 65.8%. The proposed scheme outperforms by achieving 72.6% mean PDR. If the number of nodes in the network increases to 50-node, then the average PDR of Drop Tail Scheme is 51.8%. The PAQMAN achieves 60.4%. The proposed scheme outperforms by achieving 70.2% mean PDR.

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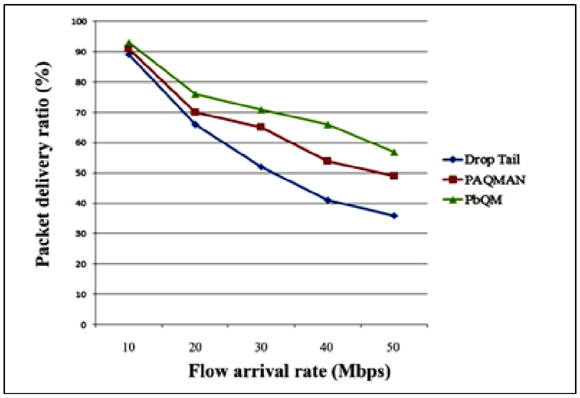

Figure 4: Packet delivery ratio for the network size of 40-nodes

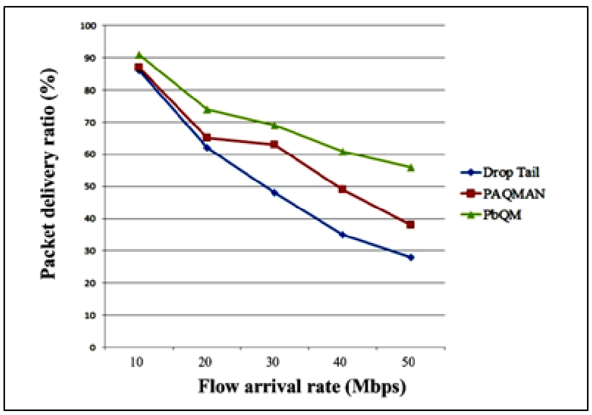

Figure 5: Packet delivery Ratio for the network size of 50-nodes

4.4 Scenario 2: Quality metrics of VoIP Packets.

The outcome of the proposed scheme using QoS markings of high priority VoIP packets is analyzed in this scenario. In order to check the impact on some QoS related system parameters, packets from different applications are marked with their priority. The VoIP packets are given the highest priority. The average throughput, end-to-end delay, and PDR of the VoIP packets are observed and compared to other tested schemes, i.e., Drop Tail and PAQMAN. In this scenario, the buffer size is increased to 500 packets to manage heavy VoIP traffic with large numbers of packets. Network traffic model is again Poisson distribution model.

Figure 6, 7, and 8 presents the performance metrics of VoIP packets (i.e. throughput, end-to-end delay and PDR) for different network size. The comparisons show that the proposed scheme, in conjunction with a traffic classification scheme, provides better throughput, end-to-end delay, and PDR of VoIP application in MANET under configured settings as compared to Drop Tail and PAQMAN schemes for tested flow arrival rates. As flow rate increases, more congestion occurs in the network because of more packet transmissions. Therefore, the overall throughput and PDR decreases whereas an end-to-end delay of VoIP application generally increases in all schemes with the rise in flow arrival rate. However, the proposed scheme outdoes other schemes in terms of performance metrics.

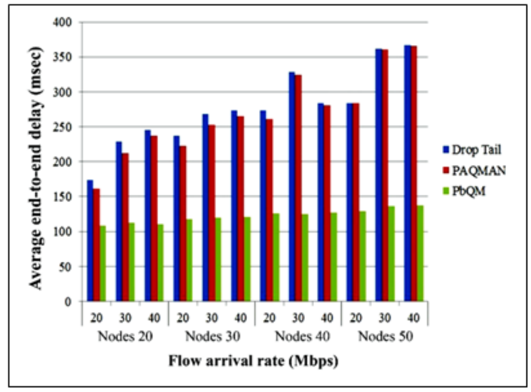

Figure 6: Average end-to-end delay with the variable flow Rate

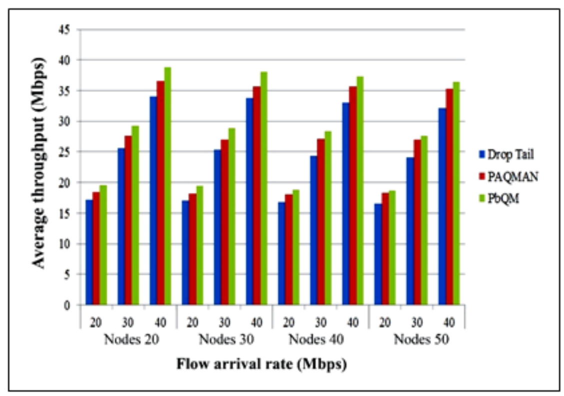

Figure 7: Average Throughput with the variable flow rate

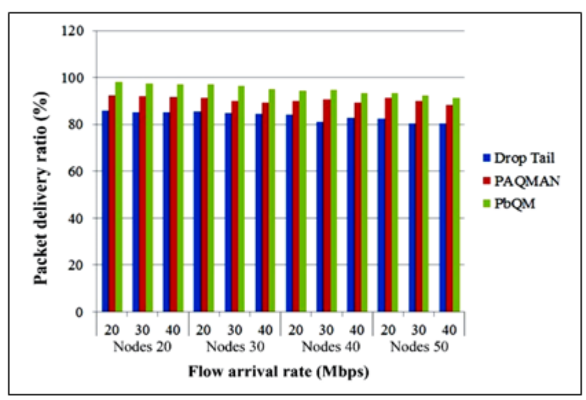

Figure 8: Packet delivery ratios with the variable flow rate

V. CONCLUSION

An enhancement is proposed in widely used Ad-hoc On-demand Distance Vector (AODV) routing protocol to deliver QoS provision for real-time applications in MANET. Whenever a node has no valid route to the intended destination, the AODV protocol buffers the packets in a queue and begins its route discovery phase by disseminating route request (RREQ) queries. Conventional AODV routing protocol uses First-in-first-out (FIFO) or drop tail queue management policy to arrange the packets in its queue. In this work, we propose Priority-based queue management (PbQM) policy for real-time packets to satisfy its QoS constraints. The proposed queue management technique is implemented in basic AODV. This new variant of AODV routing protocol, called PbQM-AODV, which improve QoS in MANET. Extensive experiments are conducted to examine the performance of PbQM-AODV in the NS-2.34 simulator and compare its performance with basic Drop tail and Predictive Queue Management (PAQMAN) techniques. The simulation results reflect the performance improvements of the proposed scheme in terms of packet delivery ratio (PDR), bandwidth and end-to-end delay.

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