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A Fuzzy-based Priority Scheduler for AODV Protocol to Support QoS Provision in MANET.

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***Abstract*—In this research work, we develop an enhancement in Ad-hoc on-demand distance vector routing protocol (AODV) to adopt a fuzzy-based priority scheduling technique that delivers Quality-of-Service (QoS) assurances to real-time applications in Mobile Ad-hoc Networks (MANET). For a given the dynamic network conditions, establishing the QoS assurance as required by hard real-time applications via conventional protocols is more challenging and a difficult endeavor in MANET. Original AODV uses static priority scheduling algorithm to organize the packets in a queue and implements drop tail policy to handle its buffer space. The proposed packet scheduling technique determines the priority index (PI) of the incoming packets under fluctuating channel states, data rate, queue length, and expiry time. The performance of the scheduling technique is analyzed via OPNET simulator and is examined in terms of QoS attributes such as throughput, packet delivery ratio, and end-to-end delay. Experimental results exhibit that the scheduler is efficient and promising. The inclusion of this scheduler increases the performance of the routing layer protocol when analyzed under various load conditions.**

***Keywords*—AODV; fuzzy-based logic, MANET; priority; QoS; queue management;**

I. INTRODUCTION

MANETs are a crew of geographically distributed mobile nodes equipped with wireless technologies which do not demand any centralized entity to provide the communication among them[1]. The fast implementation and the omnipresent access ability of MANET make them extremely appropriate for the media streaming and safety-critical real-time applicationssuch as army tactical network, medical and disaster-rescue scenarios[2]. The ad-hoc network may operate autonomously or may have gateways to connect with fixed infrastructure-based networks. Therefore, each node acts as a mobile transmitter, receiver or router of information packets. Node movement quickly leads to unpredictable topology variations and the routing protocols should be capable of preserving seamless connection in such an uncertain environment. The increasing growth of multimedia applications in mobile traffic has resulted in a shift of research interests towards better degrees of QoS rather than the best effort service. Designing of QoS routing algorithm for MANET is much more difficult and a challenging task because it has to deal with critical circumstances such as dynamic topology, frequent link failures, and energy constraints. Link quality and availability vary as a terminal travels out of or into the transmission range of other terminals [3], [4]. Wireless medium is also subject to signal interference, hidden terminal issues, multipath fading or attenuation and Doppler effects [5], [6]. These issues generate various dynamics that contribute to the high packet drop and fluctuating transmission delay. Most of the service providers fail to consider these dynamics of the network. In dynamic ad-hoc networks, complete QoS assurances cannot be delivered. Therefore, establishing these assurances as required by applications via conventional protocols is more challenging and a difficult endeavor in MANET. A good QoS routing protocol should determine appropriate routes to satisfy the QoS demands of applications and effectively use network resources. Continuous updates of link state information, e.g. delay, throughput and loss ratio, are essential to make ideal routing decisions, which result in excessive control overhead. This can be prohibitive for bandwidth bounded ad-hoc networks. Even after acquiring a path that meets the QoS demands, the channel and network dynamics make it difficult to ensure some requirements permanently.

The size of the network is also a major issue if it is vast, because the computational load will be high, and it will be hard to disseminate network updates within given time limits. When a mobile node needs to transmit packets, it enables AODV protocol to route the packet to the intended destination. The reactive AODV protocol discovers routes on demand. Hence, it stores all packets in its queue (or buffer) and initiates the route discovery process. Original AODV uses a First-in First-out (FIFO) technique to organize the packets in queue and implements drop tail policy to handle its buffer space. When the buffer is overloaded, it discards packets from the rear of the queue irrespective of their priority. With increasing concerns about the QoS constraints of multimedia applications, there is an ever greater demand in QoS enhancements for the AODV routing protocol in MANET. Since there is a variety of traffic flows in communication networks, active users may have diverse QoS demands.

Earlier research in this domain has established the significance of packet scheduling and storage space management in AODV protocol as it affects system capacity, service quality, fairness, and network performance assurances. Nevertheless, the use of shared wireless medium and time changing or multifaceted configurations make uncertain and dynamic network environment that pay incredible attention to unpredictable latency (delay). In this work, we propose a novel fuzzy-based priority scheduling technique to increase the efficiency of the network. Along with achievable data rate, queue length and the expiry time of the packet, we considered one more input, namely channel condition to determine the PI of the incoming packet. For two different channel conditions, this technique yields increased packet delivery rate, decreased overall delay and better throughput.

The reminder section of the article is structured as follows: We discuss some prior investigations which match our analysis in Section II. We describe the fundamental concepts of fuzzy-based priority schedulerin section III. The implementation and evaluation details of the proposed scheduler are given Section IV. Then, we present our conclusion in section V.

II. RELATED WORK

In the past years, considerable efforts have been devoted to compact the challenges which led to the emergence of several routing strategies which have been suggested, aiming to augment different QoS parameters, but no particular protocol affords an overall solution. The purpose of this section is to present an overview of the existing techniques in fuzzy-based packet scheduling to provide improved QoS.Zhang et. alproposed afuzzy logic control approach tofind the optimum dynamic assignment of customers to heterogeneous servers simultaneously. They implemented and evaluated two cases with server heterogeneity with respect to service rates and functions. Also, they determined the associations among them to develop control policies.Consequently, they joint this approach to queueing mechanisms with server heterogeneity in terms of service rates and functions [7].Sun et. al developed an approach to select optimized fuzzy controller variablesby means of the genetic algorithms and Wang-Mendel approach [8].The authors analyzed the performance of this methodology by simulating multimedia applications in Diff Servrealms. Ghasempour et al. designed a fuzzy-based scheduler for wireless networks. This scheduler increases PDR and decreases the overalldelay considerably [9]. Nihadet. al suggested a fuzzy logic system to improve the performance of MANET. Furthermore, they modified AODV protocol using fuzzy–based scheduler for improved QoS[10]. Pi and Sun proposed a fuzzy controller based multipath routing algorithm in an ad-hoc network to determine the PI of the packet. The proposed scheduling technique exploits three inputs (expiry time, data rate, and the queue length of the nodes) and one output (i.e. PI).

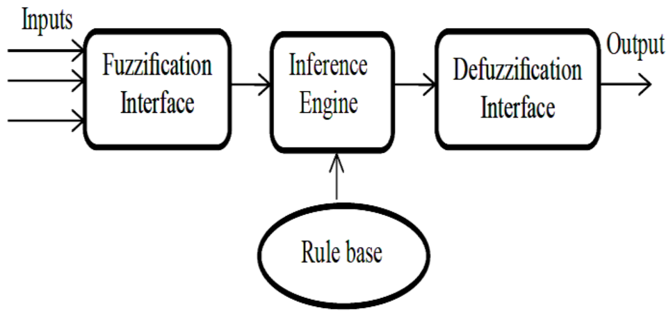

Figure 1: Fuzzy logic system

The inputs are fuzzified, implicated, aggregated and defuzzified to obtain a single crisp value of the PI [11]. In protocols without any priority scheduler, both data and control packets are maintained in a single queue and processed in FIFO fashion. In a protocol with priority scheduler, data and control packets are preserved in distinct buffers and the highest priority is set to control packets. The following discard policies are employed for the incoming packets when the queue is overflow: (i) If the received packet is a data packet, then it is discarded. (ii) If the received packet is a control packet, then the previous buffered packet is discarded, and (iii) If the buffered packet is a control packet, then the received control packet is discarded.

III. FUZZY-BASED SCHEDULING TECHNIQUE

The implementation of fuzzy logic to regulate network traffic is more striking. Since it is problematic for a network to gain through a mathematical model of the input data packets, it has to arrive at a definite conclusion only relying on imprecise data. Therefore, the decision procedure is replete with ambiguity. It is beneficial to implement the fuzzy system for regulating network traffic because it is reliable and proficient to perform with incomplete information.The fuzzy scheduler developed in this work computes PI of each incoming packet.

3.1 Fuzzy logic system

The notion of Fuzzy Logic (FL),for processing data by accepting incomplete data membership rather than crisp data set, was first introduced by LotfiZadeh [14].FL is a rule-based many-valued system; it deals human experiences and preferences through fuzzy rules with membership functions. In contrast with the conventional binary logic system, where the data set has two-valued logic: Yes or NO, fuzzy logic variables may have a value that ranges between [0,1]. It deals with imprecise, ambiguous, vague, noisy or fuzzy data (uncertain information) rather than binary choices. FL is able to process in adequate information and produce suboptimal solutions to complex problems. FL incorporates a set of simple IF-THEN rules for solving a problem instead of endeavoring to design a system mathematically. Fundamentally, the fuzzy system comprises four basic blocks as shown in Figure 1, namely, fuzzification interface, inference engine, defuzzification interface, and the rule base module [15].

The fuzzificationinterface processes the input variables and finds the degree of membership using membership function. The input is always a crisp value restricted by the universe of discourse (U) of the input and the output is the degree to which they belong to fuzzy set inU. This fuzzy set is represented as:$\{(i_1, \rho S(i_1)), (i_2, \rho S(i_2)) \ldots\ldots (i_n, \rho S(i_n))\}$,where$\rho S$:U→[0,1] and $\rho S(i_i)$ denotes the degree of i_i inS. For n inputs and a single output fuzzy system, the fuzzy base Fj can be defined by,

(F_j): IfI_1 is S_{1j}, I_2 is S_{2j}, I_3 is S_{3j},..., and I_m is S_{mj}, then B is O_j.

The variables appearing in the consequent part of F_j are input (I_i), the variable in the subsequent part of F_j is the output (O_j). The data setsS_{ij} are named as input sets of input variable I_i and the fuzzy sets B are named as output fuzzy sets of output variable O_j. Before employing the implication process, the weight of rule should be considered. Each rule has a weight (in a range between [0, 1]), which is assumed by the predecessor. As soon asthe appropriate weight has been allocated to each rule, the implication process is implemented. A consequent part of a fuzzy set is denoted by a membership function, which weighs suitably the features that areascribed to it. Additionally, it is redesigned by a function related to the predecessor. The input for the implication module is a weight specified by the predecessor, and the output is a membership function, applied for each rule.

The rules must be aggregated in a specific way to make a decision as it depends on all of the rules. In the aggregation process, the output fuzzy sets are integrated into a single fuzzy set. This process befalls only once, for each output variable, just prior to defuzzification. The list of truncated output functions reimbursed by the implication module is given as the input to aggregation. As much as fuzziness aids the rule assessment during the intermediary phases, the anticipatedoutcome for each variable is usually a crisp data. Nevertheless, the aggregation of a fuzzy data includes a range of output values, and therefore need to be defuzzified to decidea crisp value from the data set. Centroid calculation is the most prevalentde fuzzification approach, which yields the center of the area under the curve.

3.2 Fuzzy scheduler

The proposed scheduling technique exploited four inputs and one output data. The four inputs are the channel condition, queue length, the packet size and data rate of transmission. There are two terms (i.e. Good and Bad) used to denote the channel condition. For other three input variables, three terms (i.e. high, medium, and low) are used. To denote the output (i.e. PI), five linguistic variables (i.e. very high, high, medium, low, and very low) are used. Figure 2 displays the fuzzy scheduler with its member functions.

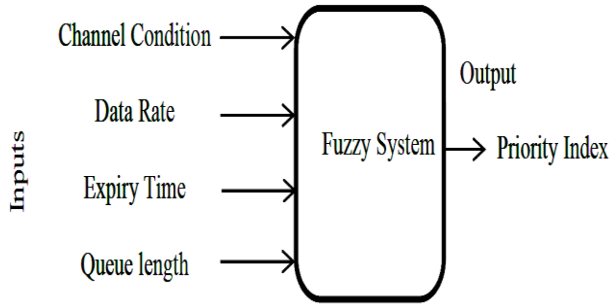

Figure 2: Fuzzy Scheduler

In order to obtain the crispy output data, the input data sets are fuzzified, implicated, aggregated, and defuzzified. Table 1 shows the knowledge base for the proposed fuzzy-based scheduling technique.

Table 1. Fuzzy rule base

D \ Q	High	Medium	Low
Channel Condition - Good			
Expiry Time-High			
High	Medium	High	High
Medium	Medium	Medium	High
Low	High	Very High	Very High
Expiry Time-Medium			
High	Medium	Medium	Medium
Medium	Low	Medium	Medium
Low	Low	Medium	Medium
Expiry Time-Low			
High	Very Low	Very Low	Low
Medium	Very Low	Very Low	Very Low
Low	Very Low	Low	Low
Channel Condition - Bad			
Expiry Time-High			
High	High	Medium	Medium
Medium	Low	Low	Low
Low	Low	Low	Low
Expiry Time-Medium			
High	Medium	Medium	Medium
Medium	Low	Low	Low
Low	Low	Low	Low
Expiry Time-Low			
High	Very Low	Very Low	Very Low
Medium	Very Low	Very Low	Very Low
Low	Very Low	Very Low	Very Low

Table 1: Fuzzy rule base represents the packets are associated with the least priority and will be processed only after processing all high priority packets. The packets with a high PI will be given the earliest opportunity to propagate. This will improve the throughput and hence the QoS of a MANET system. The surface viewer for the fuzzy scheduler is shown in Figures 3 and 4. The input data set can generate 54 possible combinations (i.e. 3*3*3*2) and the resultant output is given in Table 1. The knowledge base is divided into two sets: (i) for good channel condition, different expiry time (high, medium and low), and 9 combinations of the other two inputs(queue length (Q) and data rate (D)), and (ii) for bad channel condition, expiry time (high, medium, and low), and 9 combinations of the data rate and queue length. In order to understand the knowledge base, the first rule can be deduced as, "If the channel condition is good, the data rate is high, expiry time is high, and queue length is high, then PI is medium". As data rate and queue length are high and packets are related to medium delay. Hence, the PI is assigned to be medium. In the same way, the other rules are formed. If PI is very low, then the packets are setvery high priority and should be processed immediately. Likewise, if the PI is very high

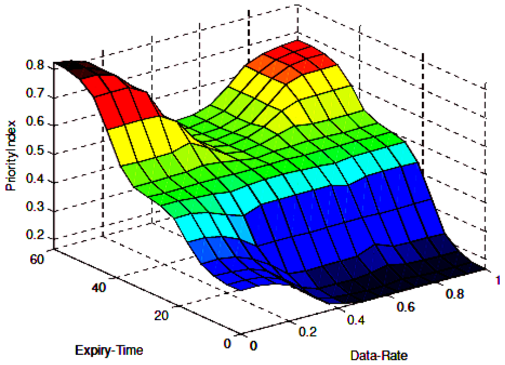

Figure 3: Surface viewer forExpiry time/data rate

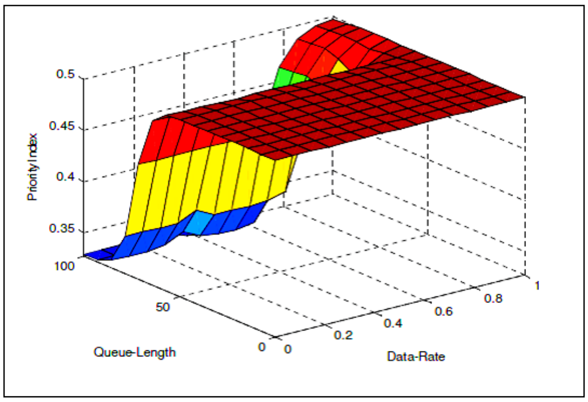

Figure 4: Surface viewer forQueue length

IV. PERFORMANCE EVALUATION

The proposed fuzzy-based scheduling technique is evaluated by Optimized Network Engineering Tools (OPNET V17.1). The algorithm is appraised using average throughput, delay, and PDR.

A. Simulation Environment

The practicality of the developed fuzzy scheduler is evaluated using OPNET. This is achieved by comparing the proposed scheduler with the two most commonly used mechanisms (i.e. Type of Service-based (ToS) scheduling and FIFO). All three network scenarios are implemented using AODV protocol and evaluated the performance of the protocol using throughput, overall delay, and PDR for video transmission. Variations in network traffic and node mobility are simulated. A 600mX600m square simulation area is considered. The application attributes have to be configured to support Video applications. Mobile nodes are designed by application definition, profile configuration, and attribute configuration. Each node is designed to travel arbitrarily at a speed of 10m/s within the confinements of the area. 2Mbps is selected as a data rate.

B. Performance Metrics

To assess the performance of the fuzzy-based priority scheduler against basic FIFO and ToS-based mechanisms, the following QoS measures are used.

Average throughput:

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

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

Average end-to-end delay (ED):

For hard real-time applications, end-to-end transmission delay or latency is considered as a primary concern used to evaluate the performance. The lesser value of delay 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. Delay is calculated in milliseconds using the following equation (2),

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

PDR:

The fraction of the number of packets reached at the target node 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. PDR is defined as,

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

C. QoS metrics for video transmission

The effectiveness of this scheduling method is related tobasic FIFO and ToS-based mechanisms with AODV routing scenarios created in the simulator in terms of packet delivery ratios. For evaluation purpose, a MANET with different node density scenarios is considered. 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 30-node is configured to evaluate the PDR of studied schemes.

The PDR is obtained in a 20-node network scenario for different flow arrival rates. 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 the light as well as dense environments of congestion. Different data rates have been selected to study the performance of queue management schemes. The results indicate that the new fuzzy schedule route performs in terms of PDR, throughput and overall delay as compared to basic FIFO and ToS-based mechanisms for various flow arrival rates.

Figure 5, 6, and 7 presents the performance metrics of video transmission (i.e. throughput, overall delay and PDR) for diverse network size. The comparisons illustrate that the developed scheme, returns better throughput, overall delay, and PDR in MANET under configured settings as compared to FIFO and ToS-based priority 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 video transmission generally improved in all schemes with the rise in flow arrival rate. However, the proposed scheme outdoes other schemes in terms of performance metrics.

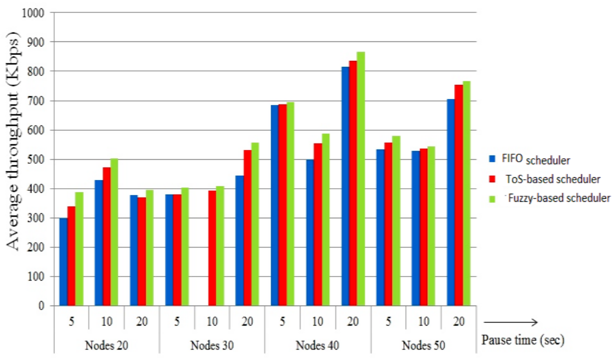

Figure 5: Average throughput

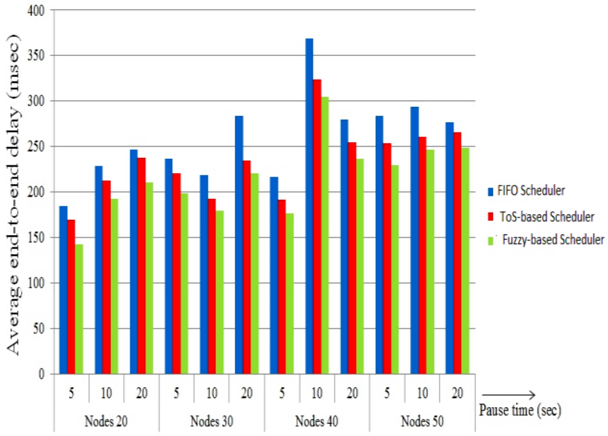

Figure 6: Average end-to-end delay

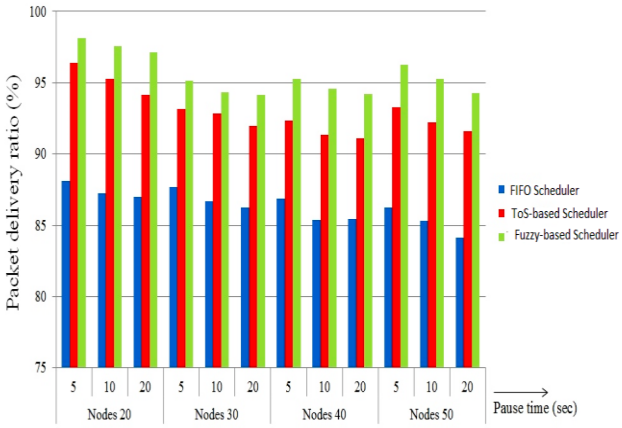

Figure 7: Packet delivery ratio

V. CONCLUSION

An enhancement is proposed in widely used AODV routing protocol to deliver QoS provision for real-time applications in MANET. Conventional AODV routing protocol uses First-in-first-out (FIFO) policy to arrange the packets in its queue. In this work, we develop a fuzzy-based scheduling technique for real-time applications to satisfy its QoS constraints. The proposed scheduler is implemented in basic AODV. This new variant of AODV routing protocol improves QoS in MANET. Experiments are conducted to examine the performance of scheduler in the OPNET simulator and compare its performance with basic FIFO and ToS-based scheduling techniques. The simulation results reflect the performance improvements of this scheme in terms of PDR, throughput, and overall delay.

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