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# ENERGY AWARE FUZZY BASED MULTI-CONSTRAINED SINGLE PATH QoS ROUTING PROTOCOL IN MANETs

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**ABSTRACT**

Routing real-time traffic with good Quality of Service (QoS) is a challenging task in Mobile Ad-Hoc Networks (MANETs). Energy Aware Fuzzy based Multi Constrained Single path QoS Routing (E-FMSQR) protocol which is an extension of AODV is proposed to find an optimal path by considering multiple QoS metrics. Considering Multi-constraints like Bandwidth, Delay, Number of Hops and Energy, a single fuzzy cost is determined as output cost. The protocol also computes Link Expiration Time (LET) based on the speed and direction of movement of the mobile node to predict the nodes mobility to identify a stable path. An optimal path is chosen as one with minimum output cost and maximum LET. Path breakage due to link failure or node failure is prevented. The simulation result shows the improvement in throughput and packet delivery ratio with minimum delay. It shows better energy distribution among nodes minimizing node failures in the network and maximizing the network Lifetime.

**Keywords:** MANET, QoS, AODV, LET.

## 1. INTRODUCTION

The proliferation of mobile devices such as cell phone, laptop and palm-top led to the demand for continuous network connectivity regardless of the physical location. An ad hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any established infrastructure or centralized administration. Ad-hoc networks possess many types of challenges like minimum Bandwidth, minimum Energy, dynamic topology and high node mobility. Due to its dynamic nature of the nodes, routing of packets becomes a challenging task. Special routing protocols were designed based on these challenges and is categorized as proactive, reactive and hybrid routing protocols. In proactive routing protocols like DSR, the path information is periodically updated and the routing information is always available [1]. The overhead incurred is high in proactive routing protocols. In reactive routing protocols like AODV, the path is identified on demand [2]. Hence control overhead is reduced compared to DSR but incurs little delay. In hybrid routing protocols like ZRP, cluster approach is followed where proactive routing is used inside the cluster and reactive routing is used between clusters [3]. The comparison of different routing approaches used in MANETs and their performance in different network conditions is shown [4] - [6]. In mobile Environment, it may be necessary for one mobile host to enlist the aid of other hosts in forwarding packets to its destination, due to the limited range of each mobile hosts wireless transmissions. A protocol for QoS routing in ad hoc networks that uses Fuzzy based Adhoc on-demand Distance Vector routing is proposed. In this protocol all the available resources of path is converted into single metric fuzzy cost. Mobility prediction is done to find the Expiration time of each link involved in a path. The path with the maximum lifetime and minimum fuzzy cost is considered to be the optimal one and used for transmission. Since Residual Energy of a node is included in fuzzy cost computation, path break due to node failure because of energy drain is reduced. The paper is organized as follows. Section II describes the works related to the routing protocol for improving QoS. Section III describes implementation of the proposed protocol using fuzzy inference engine, selection of multiple metrics and mobility prediction mechanism. Section IV describes the simulation setup used for protocol implementation. Section V shows the Performance of proposed protocol with AODV and fuzzy cost based AODV in terms of throughput, delay, packet delivery ratio and average energy. Conclusion of the work is described in section VI and section VII specifies the future enhancements of this work.

## 2. RELATED WORKS

Designing routing protocols for the networks with restricted resources is a challenge due to dynamic characteristics of their network topology. Many routing protocols has been developed for the past decade for these type of network. Quality of service support is minimum in these protocols. In literature, most of the QoS routing protocols is designed by considering single metric such as hopcount or delay or bandwidth [7]. The current routing protocols concentrate on energy of a node to identify a route [8]. Route stability is identified by computing Link Expiration Time (LET) and is used in finding path [9], [10]. Single metric is not enough to identify the best route since other parameters are affected if not considered. Hence multiple metrics are considered in identifying best route. When multiple metrics are considered to find a path that becomes an NP-Hard problem. Multiple metrics like delay, delay jitter and bandwidth along with LET computation is used to identify the route [11]. FCMQR is designed to compute fuzzy cost by taking into consideration multiple metrics like Bandwidth, Delay and Number of Hops to choose an optimal path [12]. Fuzzy

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Logic was applied on multiple metrics to compute fuzzy cost [13] - [16].

## 3. DESCRIPTION OF PROPOSED E-FMSQR PROTOCOL

An optimum path is chosen from source to destination node by choosing minimum fuzzy cost for the obtained paths and checking for the maximum Link expiration Time. The RREQ packet of AODV is modified as shown in Figure-1. Min_Bandwidth stores the minimum available bandwidth among the links for a path [12]. Sum_Delay is the sum of the delay experienced at the node and at the link along the path. Hop Count is incremented for each hop. Min_Res_Energy is the remaining energy at the node and the minimum residual energy along a path is updated. Min_LET is the minimum Expiration time of the link along the route.

| broadcast id | Destination Address | Destination Sequence no | Source Address | Source sequence no | RR Flag | Hop count | Min_ Bandwidth | Sum_ Delay | Min_ Res_ Energy | Min_ LET |
|---|---|---|---|---|---|---|---|---|---|---|

**Figure-1.** AODV route request.

### A. Implementation of fuzzy inference system

Figure-2 shows the fuzzification, rule base and defuzzification process used to compute fuzzy cost.

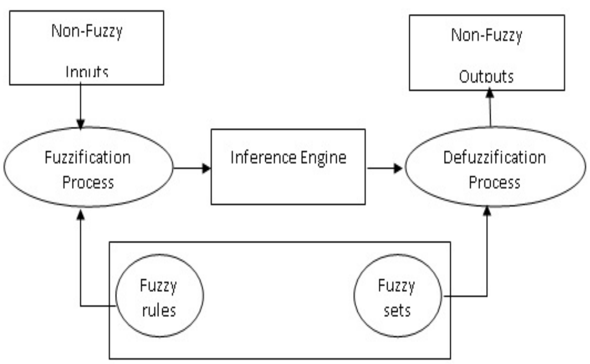


**Figure-2.** Fuzzy inference system.

### I) Fuzzification

Fuzzifier is used to map the real world inputs to the fuzzy input range (0, 1). Triangular Membership function is used for fuzzification of inputs as shown in Figure-3. The input values for Throughput, Delay, hopcount and Energy is fuzzified to have low, medium and high values. The output fuzzy cost has very low, low, medium, high and very high values.

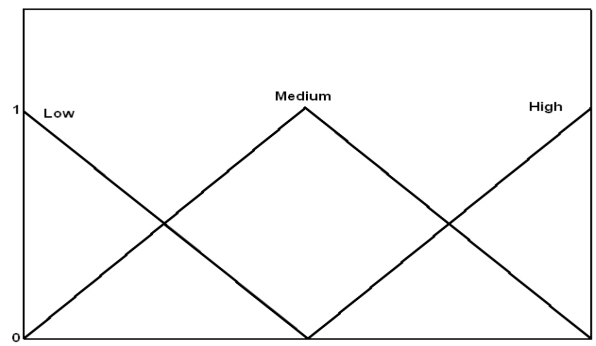


**Figure-3.** Triangular membership functions for Bandwidth, delay, hop count and energy.

### II) Fuzzy rules

Table-1 implies the fuzzy rules applied for input and output parameters. Fuzzy rules are based on IF-THEN statements.

For Example, IF (Bandwidth is “High”) and (End To End Delay is “Low”) and (No. of Hops is “Short”) and (Energy is ”High”) then Output Cost is “Very Low”.

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**Table-1.** Fuzzy rules for route selection.

| Bandwidth | End to end delay | No. of hops | Energy | Cost |
|---|---|---|---|---|
| Low | Low | Short | Medium | Low |
| Medium | Low | Short | Medium | Low |
| High | Low | Short | Medium | Very Low |
| Low | Medium | Medium | Medium | High |
| Medium | Medium | Medium | Medium | Medium |
| High | Medium | Medium | Medium | Low |
| Low | High | Long | Low | Very High |
| Medium | High | Long | Medium | High |
| High | High | Long | High | High |
| Low | Medium | Short | Low | Medium |
| Medium | Medium | Short | Medium | Low |
| High | Low | Short | High | Very Low |

**III) Defuzzification**

Defuzzifier produces a real-world output from the fuzzy outputs which are in the range [0, 1] by using defuzzification techniques. There are many types of defuzzifiers used for defuzzification. Since the main objective of proposed approach is to choose an optimal path with the best fuzzy cost, it doesn't require the fuzzy outputs to be defuzzified. Results can be derived by comparing the fuzzy costs itself. As an example, suppose if the system outputs two paths P1 and P2, then the best path can be derived as follows without further defuzzifying the fuzzy outputs:

*If FuzzyCost(P1) < FuzzyCost (P2) then Best path= P1*
*Else Best path = P2.*

**B. Mobility prediction mechanism**

In mobile ad hoc network, the reliability of a path depends on the stability or availability of each link of this path because of the dynamic topology changes frequently. It supposes a freespace propagation model where the received signal strength solely depends on its distance to the transmitter. Therefore, using the motion parameters (such as speed, direction, and the communication distance) of two neighbours, the duration of time can be determined in order to estimate that two nodes remain connected or not. Suppose two nodes "i"and "j" are within the transmission distance "ra" between them, let (xi, yi) and (xj, yj) be the coordinate of mobile host "i" and mobile host "j". Also let (vi, hi) be the speed and the moving direction of node "i", let (vj, hj) be the speed and the moving direction of node "j". The link expiration time (LET) is computed by

$$LET(i,j) = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r_a^{\,2}-(ad-bc)^2}}{(a^2+c^2)} \qquad (1)$$

Note that a =i coshi - j coshj, b= xi -xj, c = i sinhi - j sinhj,and d =yi - yj. Note also that the eq.(1) cannot be applied when i =j and hi = hj. When LET is in order to get and utilize the information from Geographical Positioning System (GPS), the packets must include extra fields. When a source node sends a request packet, the packet appends its location, direction and speed. The next hop node from the source node receives the request packet to predict the duration of time between itself and the source node. If node B is the next hop of the packet for node A, node A will insert its location information in the packet so node B will be able to compute the duration of time between node A and node B.

**C. Description of multiple selections parameters**

Most of the current routing protocols in MANETs are designed by taking single selection metric like the bandwidth or delay or number of intermediate hops or remaining battery power of the intermediate nodes to find a route. The disadvantage of using a single metric is that it satisfies only one criterion, affecting others like either maximizing throughput, maximizing packet delivery fraction, minimizing delay or increasing battery life. Therefore, efficient routing in MANETs requires selecting routes that meet multiple metrics. The proposed routing protocol is designed to consider multiple metrics like Throughput (T), End-to-End Delay (D), Energy (E) and Number of Hops (N).

The relationship between the cost function C and the other metrics is given by

$$C= f(B, D, N, E) \qquad (2)$$

The bandwidth calculating function is defined as the minimum number of available free slots between two nodes in a path.

$$B (P(s,d))=\min\{bandwidth(e), e \in p(s,d)\} \qquad (3)$$

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The end-to-end delay of a path is the summation of the node delay at each node and the link delay on the path.

D(p(s,d) = min(Σe €p(s,d)delay(e)+ Σe €p(s,d)delay(n)) (4)

Where p(s, d) denotes the path from source "s" to destination node "d" and "e" is any link between two nodes along the path.

The node remaining energy is the residual energy left after the packet transmission (i.e.) residual energy $Energy_{res}$ is given by

$$Energy_{res}=Energy_{initial}-(Energy_{trans}+ Energy_{idle}) \quad (5)$$

**D. Proposed algorithm**

RREQ packet of AODV is extended with four fields namely Min_Bandwidth, Sum_Delay, Min_LET, Min_Res_energy. The source node before sending RREQ packet, checks its own routing table for destination, if it has a route, it reserves resources and forwards the data packet. If there is no route information, it broadcasts the RREQ packet to the intermediate nodes. Min_Bandwidth among the links which the RREQ is broadcasted is updated based on eq.(3). Sum_delay is updated by adding the link delay and node delay as per eq (4). Hop count incremented by 1 for each hop. Res_Energy is computed using eq(5) and min_energy among the nodes is updated. LET is computed based on eq (1) and minimum of the LET is updated in the RREQ packet. At the Destination, RREQ packet arrives with different paths with different input values for the considered metrics. Fuzzy rules are applied and the fuzzy cost is computed based on eq (2). The route satisfying minimum cost and maximum Link Expiration time is selected. Selection of Maximum Expiration Time ensures high path stability. Energy parameter included for computing fuzzy cost ensures the node with minimum energy is not selected. As a result, path breakage due to Energy drain is avoided which enhances packet delivery ratio and minimizes the control overhead required to find a new path due to node failure.

## 4. SIMULATION MODEL

The simulation tool used is NS-2. The simulation area is 1000 x 1000 square meters. A node's speed is uniformly distributed in the range of (0, 10) meters per second, and the wireless transmission range is 250 meters. Number of nodes in the network is set to 100 nodes. A traffic flow is constant bit rate (CBR), each of which randomly starts and have a bit rate of 4 packets per second, each packet size is 512 bytes. Each simulation runs for 100 seconds of simulation time. Mobile nodes move within the simulation area according to the random way point mobility model. Initial energy used in all nodes is 100J.

## 5. PERFORMANCE EVALUATION OF F-MSQR USING NS-2

The performance of E-FMSQR protocol is evaluated through NS-2 simulator and is compared with AODV [2] and FCMQR [13].

**a. Simulation results of E-FMSQR**

The comparison of the proposed protocol with AODV and FCMQR is shown below.

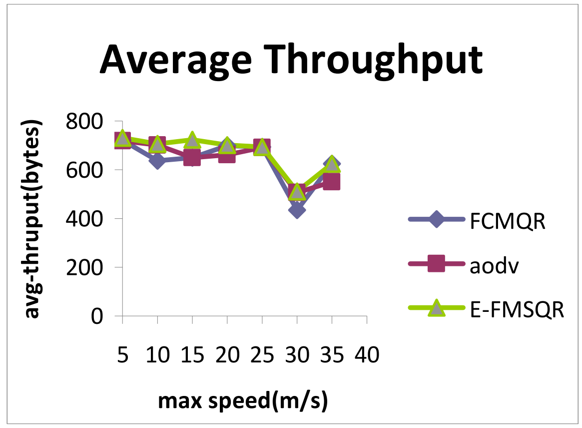


**Figure-4.** Effect of average throughput for various mobility speed of the nodes.

Effect of average throughput for various speeds of mobile nodes is shown in Figure-4. E-FMSQR achieves a higher throughput than AODV and FCMQR.

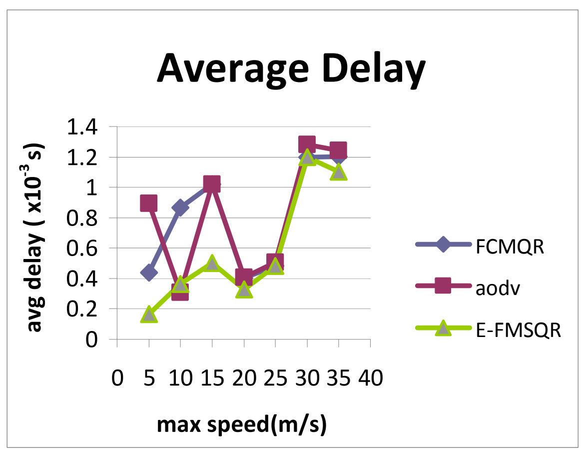


**Figure-5.** Effect of average delay for various mobility speed of the nodes.

The performance of the average end-to-end delay under various mobility speeds is shown in Figure-5. End to End delay is significantly less in E-FMSQR compared to AODV and FCMQR even at higher mobility environment. The decrease of delay is due to choosing a path with higher lifetime which reduces the route breakage due to link failure and prevents drain of energy in a node. AODV and FCMQR suffers frequent link breaks and

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needs route reconstruction frequently which results in increasing average end-to-end delay.

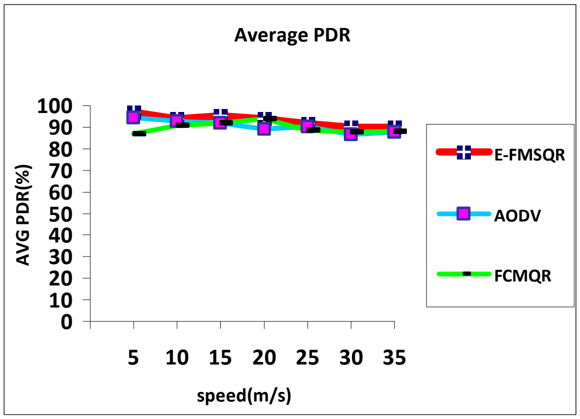


**Figure-6.** Effect of average PDR on various mobility speed of the nodes.

The performance of the average PDR is shown in Figure-6. In E-FMSQR, multiple constraints with energy of the node is taken into account which avoids path breakage due to node failure and the most stable path is also identified with maximum LET. Hence packet drop due to path break is reduced which enhances the Packet delivery ratio compared to AODV and FCMQR.

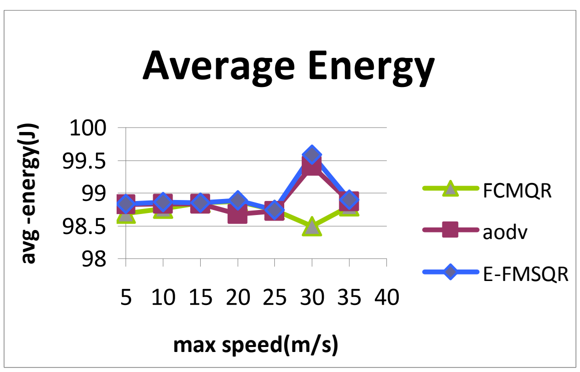


**Figure-7.** Effect of average energy on various mobility speed of the nodes.

The performance of average energy is shown in Figure-7. Energy utilization is less for E-FMSQR when compared to AODV and FCMQR because always the node with higher residual energy is chosen, hence average energy of the nodes remain maximum.

## 6. CONCLUSIONS

The designed protocol selects the routing path by computing the fuzzy cost and Link Expiration Time. Fuzzy rule base is developed by considering different metrics like bandwidth, end-to-end delay, energy and number of hops to generate a single cost value, which is used for route selection. Stable path is chosen by selecting path with minimum fuzzy cost and maximum link expiration time along the path.

## 7. FUTURE SCOPE

In future the technique can be enhanced to identify multiple paths to distribute the packets along identified feasible paths for load balancing. The algorithm can also be applied to test QoS parameters for real time traffic, Multimedia services like video streams and voice traffic. The algorithm can also be compared with other optimization techniques like genetic algorithm, ant colony optimization.

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