Fuzzy Logic QoS Dynamic Source Routing for Mobile Ad Hoc Networks

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Abstract- Routing protocols in MANET, generally, can be categorized as table-driven and on-demand. In on-demand each node seeks for routes only when there is need to do so. This category also called as reactive protocol. The examples of on-demand routing protocol are DSR, AODV, ZRP and DSR-ARM. In some regular situation, some links in the route may fail. In this situation, any packets that travel through these routes will be lost or dropped. In some cases any packets may still reach its destination, but with some delay, where the packet delay and packet delivery is the main concern. QoS support in mobile ad hoc networks has become an important area of research. Hence there is an opportunity in improving the QoS. Compared to the demands of traditional data-only applications, these new requirements generally include high bandwidth availability, high packet delivery ratio and low delay rate. In ad hoc networks, we propose an extension QoS routing algorithm based on dynamic source routing protocol while adopting Fuzzy logic to select appropriate QoS routings in multi path. The algorithm can tolerate High degree of information imprecision by adding the fuzzy logic module which integrates the QoS requirements of application and routing QoS parameters to determine the most qualified node. This scheme considers not only the bandwidth and end to end delay of the routing but also the cost of the path. So it also improves the network performance.

Index terms- MANET; DSR; QoS; Fuzzy logic.

1. INTRODUCTION

A Mobile Ad-hoc Network (MANET) is a temporary wireless network composed of mobile nodes, in which an infrastructure is absent. If two mobile nodes are within each other's transmission range, they can communicate with each other directly; otherwise, the nodes in between have to forward the packets for them. In such a case, every mobile node has to function as a router to forward the packets for others. Thus, routing is a basic operation for the MANET. Because traditional routing protocols cannot be directly applied in the MANET, a lot of routing protocols for unicast, multicast, and broadcast transmission have been proposed since the advent of the MANET [1].

DSR protocol is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad-hoc networks of mobile nodes. It is an on-demand routing protocol that is based on the concept of source routing and composed of two phases: route discovery and route maintenance. To achieve this goal, the DSR Route Request control packet is modified by adding a new field that will be used to determine the acceptance level of available bandwidth. The mobile node must have to allow data traffics to pass through reaching the destination nodes. In order to test the proposed model, a simulation model is implemented using the network Simulator (Omnet++) and different scenarios were tested to see the performance of the modified protocol compared with the original DSR protocol. The results show that not all routes from source to the destination chosen by the DSR routing protocol are suitable for real time traffic transmissions, since there is no QoS considered in the routing protocol; whereas the DSR with QoS shows extremely good results, where the transmission delay is not desired. Also, pure DSR protocol consumes channel and node bandwidth due to large amount of routing packets generated to establishing routes and both protocols are operation well in low congestion network. Thus, from simulation results and analysis, it can be seen that adding QoS to routing protocol is meaningful to optimize the performance of traffic on the network; especially the real time traffic [2].

One more work, Multipath Dynamic Source Routing (MP-DSR), which is based on DSR, i.e., both protocols work quite similar. MP-DSR uses reliability requirements for end-to-end routes [3-5]. This reliability is defined by the probability of having a successful transmission between the nodes. Thus some kind of QoS is provided. The calculation of the end-to-end reliability probability is based on the link availability of the intermediate nodes, which is given by their movements. MP-DSR determines two values for a route: the amount of paths needed to discover and the lowest path reliability that must be fulfilled for a path. When there are less routes between

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the end nodes, more reliable routes are preferred, accordingly the reliability requirement is higher. After these two values are set, the source node sends out the Route Request (RREQ) for the set amount of paths. Each message contains additional information including the reliability requirement, the path it has traversed, the corresponding path reliability, etc. At an intermediate node, the RREQ-packet is checked whether this message meets the path reliability requirement. If so, the RREQ-packet is dropped, otherwise the intermediate node adds itself to the RREQ and sends out multiple copies of this updated RREQ to its neighbors. The amount of sent RREQ-packets by the source is based on the number of neighbors that can receive this RREQ without failing the path reliability. When the destination receives the RREQ-packets, it selectively chooses multiple node-disjoint routes and sends back RREP-packets accordingly. Mobile Ad hoc networks have several silent characteristics such as dynamic topology, bandwidth constrained, variable capacity links, energy constrained operation and physical security etc.Since the nodes in mobile Ad hoc network acts as a router and host, the routing protocol is the primary issue and has to be supported before any application can be deployed for any ad hoc wireless network.

In our scheme we consider mainly the implementation and popularization of QoS routing. In this paper we modified DSR to support QoS functions because it can achieve good performance in MANET which includes the nodes less than hundred level. In MANET the imprecise information due to dynamic topology is the main problem, we used Fuzzy theory to solve it. In this scheme we found multi path between source and destination by using MP-DSR protocol and among multiple paths one of the appropriate path is selected for application using Fuzzy logic [6-9].

2. DYNAMIC SOURCE ROUTING (DSR)

Dynamic source routing protocol (DSR) is an on-demand, source routing protocol, whereby all the routing information is maintained (continually updated) at mobile nodes. DSR allows the network to be completely self-organizing and self-configuring, without the need for any existing network infrastructure or administration. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations in the ad hoc network.

2.1 Route Discovery

DSR search for some routes from source node to destination node are as follows; first source node will start

to "flood" the network with route request (RREQ) packets (assumed source node does not have any route to reach destination node before).Intermediate nodes, then will check whether it is by itself the destination node or not. If this node is not the destination node, then this node will add itself into the route list in the RREQ packet header and then forward this packet into its neighbors. If this node is the destination node, then this node will send route reply (RREP) packet to the originator of this RREQ packet (i.e. source node), including the route list to reach this particular node, which was gathered from RREQ packet header. How the RREP packets travel to reach source node is just simply by following the route list. To return the Route Reply, the destination node must have a route to the source node. The major dissimilarity between this and the other on-demand routing protocols is that it is beacon-less and hence it does not have need of periodic hello packet (beacon) transmissions, which are used by a node to inform its neighbors of its presence. The fundamental approach of this protocol during the route creation phase is to launch a route by flooding Route Request packets in the network. The destination node, on getting a Route Request packet, responds by transferring a Route Reply packet back to the source, which carries the route traversed by the Route Request packet received.
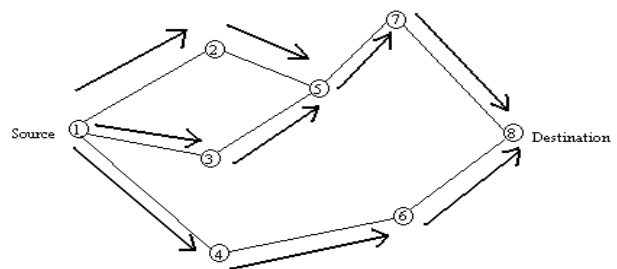
(a). Propagation of request (PREQ) packet.
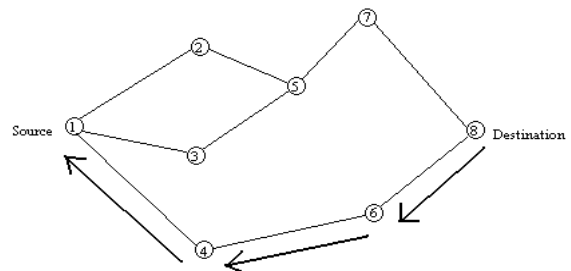
(b). Path taken by the Route Reply (RREP) packet.

Figure 2.1 Creation of route in DSR.

A destination node, after receiving the first Route Request packet, replies to the source node through the reverse path

the Route Request packet had traversed. Nodes can also be trained about the neighboring routes traversed by data packets if operated in the promiscuous mode. This route cache is also used during the route construction phase. If an intermediary node receiving a Route Request has a route to the destination node in its route cache, then it replies to the source node by sending a Route Reply with the entire route information from the source node to the destination node.

2.2 Route maintenance

In case of link/route failure, the intermediate nodes, which detect link/route failure, will send route error (RERR) packet to the source node. When source node receives RERR packet, it will try to find alternative routes from its route cache. If alternative routes are not available, source node, then, will enter route discovery phase to find new routes. Although DSR can respond a route quickly, unfortunately it yields a long delay when a route is rebuilt. Finding a route in wireless network require considerable resources, such as time, bandwidth and power because it relies on broadcasting.

3. FUZZY LOGIC

3.1 Introduction

The past few years have witnessed a rapid growth in the number and variety of applications of fuzzy logic (FL). FL techniques have been used in image-understanding applications such as detection of edges, feature extraction, classification, and clustering. Fuzzy logic poses the ability to mimic the human mind to effectively employ modes of reasoning that are approximate rather than exact. In traditional hard computing, decisions or actions are based on precision, certainty, and vigor. Precision and certainty carry a cost.

3.2 Fuzzy Sets and Membership Functions

Zadeh introduced the term fuzzy logic in his seminal work "Fuzzy sets," which described the mathematics of fuzzy set theory (1965). Plato laid the foundation for what would become fuzzy logic, indicating that there was a third region beyond True and False. It was Lukasiewicz who first proposed a systematic alternative to the bivalued logic of Aristotle. The third value Lukasiewicz proposed can be best translated as "possible," and he assigned it a numeric value between True and False. Later he explored four-valued logic and five-valued logic, and then he declared that, in principle, there was nothing to prevent the derivation of infinite-valued logic. In a crisp set, membership or nonmembership of element x in set A is described by a characteristic function , where and . Fuzzy

set theory extends this concept by defining partial membership. A fuzzy set A on a universe of discourse U is characterized by a membership function that takes values in the interval. Fuzzy sets represent commonsense linguistic labels like slow, fast, small, large, heavy, low, medium, high, tall, etc. A given element can be a member of more than one fuzzy set at a time. A fuzzy set A in U may be represented as a set of ordered pairs. Each pair consists of a generic element x and its grade of membership function; that is, i n, x is called a support value if . A linguistic variable x in the universe of discourse U is characterized by and , where is the term set of x — that is, the set of names of linguistic values of x, with each Tx i being a fuzzy number with membership function µx i defined on U. For example, if x indicates height, then may refer to sets such as short, medium, or tall. A membership function is essentially a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. As an example, consider a fuzzy set tall. Let the universe of discourse be heights from 40 inches to 90 inches. With a crisp set, all people with height 72 or more inches are considered tall, and all people with height of less than 72 inches are considered not tall. The crisp set membership function for set tall is shown in Figure 3.1. The corresponding fuzzy set with a smooth membership function is shown in Figure 3.2. The curve defines the transition from not tall and shows the degree of memberships for a given height.
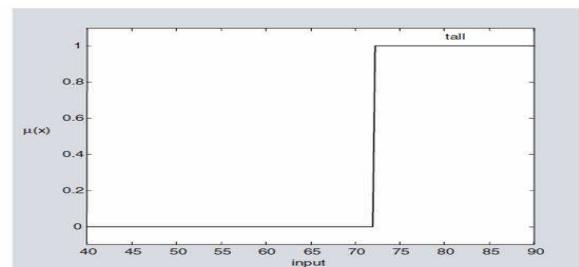
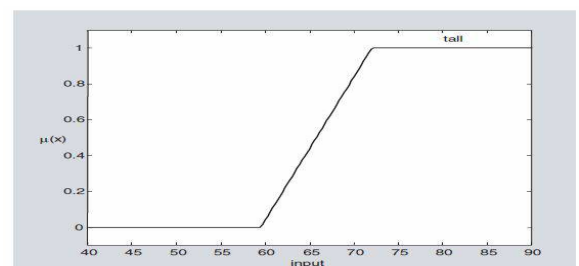

Figure 3.1 crisp membership functions.

Figure 3.2 an example of a fuzzy membership function.

We can extend this concept to multiple sets. If we consider a universe of discourse from 40 inches to 90 inches, then, to describe height, we can use three term values such as short, average, and tall. In practice, the terms short, medium, and tall are not used in the strict sense. Instead, they imply a smooth transition. Fuzzy membership functions representing these sets are shown in Figure 3.3. The Figure shows that a person with height 65 inches will have membership value 1 for set medium, whereas a person with height 60 inches may be a member of the set short and also a member of the set medium; only the degree of membership varies with these sets. Various types of membership functions are used, including triangular, trapezoidal, generalized bell shaped, Gaussian curves, polynomial curves, and sigmoid functions. Figure 3.3 shows trapezoidal membership functions. Triangular curves depend on three parameters a, b, and c and are given by

$$f(x;a,b,c,)=$$

$$\begin{cases} 0, & x \triangleleft a \\ x-a \div b-a & for, a \le x < b \\ c-x \div c-b & for, b \le x \le c \\ 0 & for, x > c \end{cases} \rightarrow 3.1$$
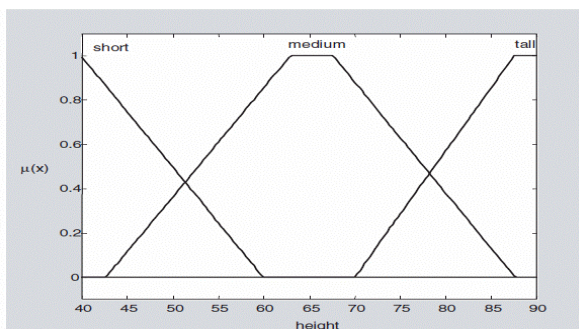

Figure 3.3 Trapezoidal membership functions.

Trapezoidal curves depend on four parameters and are given by

$$f(x;a,b,c,d)=\begin{cases} 0, & for x < a \\ x-a \div m-a, & for a \le x < b \\ 1, & for b \le x < c \\ d-x \div d-c, & for c \le x < d \\ 0, & for x \ge d \end{cases} \rightarrow 3.2$$

Where S(x;a,b,c) represents a membership function defined as

$$S(x;a,b,c,)=\begin{cases} 0 & for x < a \\ 2(x-a)^2 \div (c-a)^2 & for\ a \le x < b \\ 1-(2(x-c)^2 \div (c-a)^2) & for b \le x \le c \\ 1 & for x > c \end{cases} \rightarrow 3.3$$

In Equation (3.3), a, b, and c are the parameters that are adjusted to fit the desired membership data. In designing a fuzzy inference system, membership functions are associated with term sets that appear in the antecedent or consequent of rules.

3.3 Fuzzy Inference System

A fuzzy inference system (FIS) essentially defines a nonlinear mapping of the input data vector into a scalar output, using fuzzy rules. The mapping process involves input/output membership functions, FL operators, fuzzy if–then rules, aggregation of output sets, and defuzzification. An FIS with multiple outputs can be considered as a collection of independent multi-input, single-output systems. A general model of a fuzzy inference system (FIS) is shown in Figure 3.4. The FLS maps crisp inputs into crisp outputs. It can be seen from the figure that the FIS contains four components: the fuzzifier, inference engine, rule base, and defuzzifier. The rule base contains linguistic rules that are provided by experts. It is also possible to extract rules from numeric data. Once the rules have been established, the FIS can be viewed as a system that maps an input vector to an output vector. The fuzzifier maps input numbers into corresponding fuzzy memberships. This is required in order to activate rules that are in terms of linguistic variables.

4. PROPOSED WORK

In ad hoc networks, we propose an extension QoS routing algorithm based on dynamic source routing protocol while adopting Fuzzy logic to select appropriate QoS routings in multi path. The algorithm can tolerate high degree of information imprecision by adding the fuzzy logic module which integrates the QoS requirements of application and routing QoS parameters to determine the most qualified node. This scheme considers not only the bandwidth and end to end delay of the routing but also the cost of the path. So it also improves the network performance. On the other hand merit of using fuzzy logic is that it can be implemented by hardware. This makes the realization of scheme easier and faster.

4.1 FLQDSR: Fuzzy logic QoS DSR

A usual routing algorithm includes two parts: Route discovery and route maintenance.

4.1.1Route discovery

The routing in FLQDSR consists of mainly three components: a) the establishment of multiple paths between source node and destination node, by using modified DSR, (b) collection of the link state and the total route state, and (c) computation of the most qualified route for application requirement through fuzzy controller.

4.1.1.1 Multiple paths Establishment

The mechanism of route discovery, of DSR, can be used to find the multiple paths, between source and destination nodes, in the Mobile ad hoc network. This is called as multi path DSR. However in DSR the data is sent out once the route is found. Multi-paths can only be used in route maintenance phase. In FLQDSR the data transmission can be initiated only after multi paths are discovered between source and destination nodes.

4.1.1.2 Link state collection

In usual QoS routing algorithm only consider to search feasible routing. It is the precondition that the node gets and keeps the up to date local state about all outgoing links. The state information link (i,j) contains, a)delay(i,j), including propagation, queuing and protocol processing delay. b) The residual bandwidth (i,j) , and c) cost(i,j), which can be defined according to the conditions. In each node the collection of local state is taken charge by MAC layer protocol. It can be either by adding such functions on present MAC layer or by adopting directly a MAC protocol which is designed for this request. In our simulation we modified 802.11 to collect the delay between the node and neighboring nodes through Hello message, the residual bandwidth is calculated by resource reservation function

A path. P= i->j->........m->n QoS metric can be defined as follows:
Delay (P) =delay (i,j)+……+delay(m,n)
Bandwidth (P)=cost(i,j)+………+cost(m,n)

The path QoS state collection depends on the propagations of route reply (RREP).Three new fields are added in to DSR RREP message format. The route cache entry is also modified to conserve the information. When the destination node initiates the RREP, it will insert its local state in RREP. Then the intermediate node replaces the corresponding fields in the message according to the RREP information and its own state. At last the source node can acquire the path QoS state.

4.1.1.3 Fuzzy QoS Route Choosing

The main module of FLQDSR is shown in above figure. It identifies which route in multiple paths provides most appropriate QoS to application request. With the dynamic variation of network topology, the network status and control action are determined in an imprecise environment. Fuzzy logic is proposed to solve such nebulous questions. The block diagram shown in Fig 4.1 is a fuzzy controller. It consists of three sub fuzzy controllers and a route selecting module:

a) The Fuzzy process of application QoS requirements
b) The selected QoS parameters fuzzy handle
c) The fuzzy matching between outputs of both (a) and (b).
d) Route selecting.

The fuzzy membership functions used in solutions of our problem are continuous functions of two kinds triangular tri(x;a,m,b) and trapezoidal trap(x;a,m,n,b) as described in equations 4.1 and 4.2, where m and n are modal values, a and b represents the upper and lower bounds respectively, for non zero values of tri(x) and trap(x).

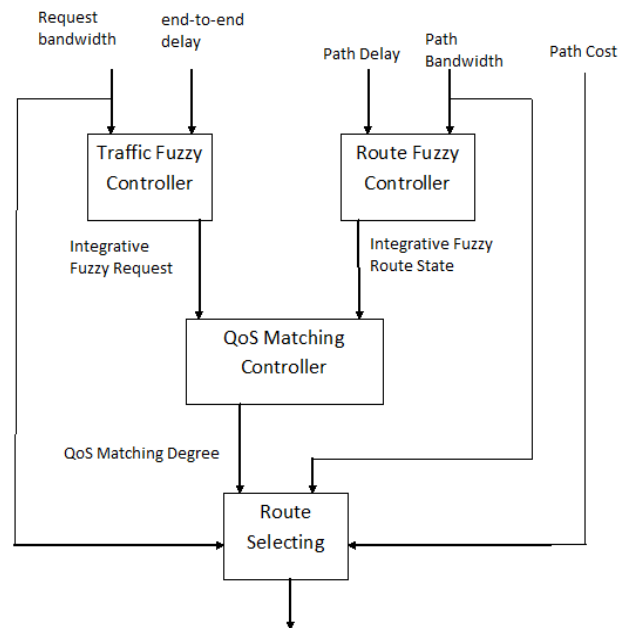Fig 4.1 Structure of fuzzy controller

$$\mathbf{Tri(x;a,m,b)}=\begin{cases}0, x\le a\\ x-a\div m-a, x\in(a,m) & a\neq m\\ 0, a=m\\ b-x\div b-m, x\in(m,b) & b\neq m & \rightarrow 4.1\\ 0, b=m\\ 0, x\ge b\end{cases}$$

Fuzzy Set	Type Function	Parameter Function
~S	Tri	[0,0,10]
~M	Trap	[0,12,25,50]
~L	Trap	[25,50,100,100]

Fuzzy Set	Type Function	Parameters Function
~R1	Tri	[0,0,300]
~R2	Trap	[200,400,600,800]
~R3	Trap	[600,800,1000,1200]
~R4	Trap	[1000,1200,1400,1600]
~R5	Trap	[1400,1600,1800,2000]

$$\textbf{Trap(x;a,m,n,b)}=\begin{cases}0, x\le a\\ x-a\div m-a, x\in(a,m)\\ 1, x\in[m,n]\\ b-x\div b-n, x\in(n,b)\quad\quad b\ne n\\ 1, b=n\\ 0, x\ge b\end{cases}\quad\rightarrow 4.2$$

a) Traffic Fuzzy controller

In this element, the application request and end to end delay are entry variables. The output is integrative fuzzy request according to linguistic rules. The keys of controller design are two aspects: One is the fuzzy mappings of entry variables and their membership functions; the other is the foundation of defining the fuzzy rules. Considering the mobile feature of MANET, the universe of discourse of bandwidth is [0, 2Mbps].According to experience the request bandwidth is divided into five classes "lower, low, medium, high, higher". They are presented as fuzzy sets "~R$_1$, ~R$_2$, ~R$_3$, ~R$_4$, ~R$_5$ "respectively in table 1.The graphical representation of the same is shown in Fig 4.2. At present real time application includes voice and video. Their average requirements of end to end delay are limited in 5ms and 25ms respectively. So the linguistic variable "End to end delay" is presented by "short, middle, long" Fuzzy sets shown in table 2.Fig 4.3 shows graphical representation of membership function for "end to end delay". The fuzzy rules can be defined through experts, experience or other principles .Since there are not enough

application research fo fuzzy sets in MANET, it is hard to depend on experience to design rules. The fuzzy decision theory can be used to determine the rules. All linguistic rules are shown in table 3.

Table 1 "request bandwidth" fuzzy set

Table 2 "End to End Delay" fuzzy set

b) Route Fuzzy controller

This controller is responsible for the fuzzy process of route QoS statements its structure is the same as the traffic fuzzy controller. The difference is that the input variables are the path bandwidth and path delay. The out put is integration fuzzy route state. The representation of Path bandwidth is change to (B1, B2, B3, B4, and B5).

c) QoS Matching Controller

The control rules of this element are based on the matching degree (MD) between" Integrative fuzzy request" and "integrative fuzzy route state"

$$MD=\begin{cases}1\quad for\quad\quad Fuzzy\ request=Fuzzy\ route\ state\\ 0, other\end{cases}$$

If the MD is one then the route is selected as effective one; otherwise it is invalid.

Table 3 Linguistic Rules of "Traffic Fuzzy Controller" (RB: Request Bandwidth   D: End to End Delay)

RB \\ D	~R1	~R2	~R3	~R4	~R5
~S	Higher	Higher	Higher	Higher	Higher
~M	Medium	Medium	Medium	Medium	Medium
~L	Lower	Low	Medium	High	Higher

d) Route selecting algorithm

From all the valid routes the most appropriate QoS route is through the algorithm described as follows.
Step1:
If the "Path bandwidth" >= "Request bandwidth", the process turns to step 2 else, jump to step 4.
Step2:

If there are two or more paths which is satisfy the condition of Step1, compare their "path cost ", the route which has least cost will be selected. Then the program enters step3.Otherwise the present route that is satisfied the requirement is the selecting result .The program also turns to step3.

Step3:
Start-up the bandwidth reservation program to reserve the requirement on each link of selected path. Then sends the data packets to destination. When the application session is finished, the reserved bandwidth will be freed.

Step4:
If no route is satisfied the condition, this route request of route is refused.

4.1.2 Route Maintenance
When there are some paths broken due to mobility or exit of nodes, the source node gets the failure information through the RERR message and modifies the corresponding entry in the route cache. This mechanism same as the route maintenance in DSR. If source node has valid path to destination in its route cache then another session that has QoS requirement is initiated.

CONCLUSION
 We here proposes a QoS routing scheme that is improved DSR and adopted fuzzy logic to decide to most qualified route for mobile ad hoc network, because DSR can achieve good performance. This scheme is suitable for small scale (nodes less than 100) MANETs. As advantage of this method, it can be listed that supporting unidirectional link, the greater flexibility of route choosing and possibility to include more information from traffic and network status in order to take decision without a considerable increase in controller complexity. In this scheme multiple effective QoS routes are found, from source to destination, and an appropriate route is selected among multiple routes. During the failure of one of the link in selected route, an alternate available appropriate route is selected if available. Otherwise new route is discovered. Though FLQDSR is not suitable for large scale MANETs, but the basic idea of fuzzy logic can be extended to AODV.

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