Bandwidth and Delay Guaranteed Unicast Routing in Mobile Ad hoc Networks using Fuzzy Logic

Mamata J. Sataraddi, Vijayashree R. Budyal

Abstract — **Mobile Ad hoc Networks comprises of mobile nodes that are communicating via either single-hop or multi-hop wireless links through a sequence of intermediate nodes. They are an autonomous collection of mobile hosts connected by wireless links with no fixed infrastructure. A unicast communication provides an efficient connectivity between the source and destination through intermediate mobile nodes. Mobility of the hosts necessitates, maintenance of Quality of Service for unicast routing for real time applications. This paper proposes, fuzzy logic based unicast routing in Mobile Ad hoc Networks considering uncertain and imprecise parameters like bandwidth, link delay and link reliability to assure Quality of Service. The work selects a reliable, bandwidth and delay aware intermediate nodes between source and destination to provide the required Quality of Service for applications like audio, video etc. To test the performance effectiveness of the approach, we have analyzed the performance parameters like route discovery time, bandwidth utilization and QoS acceptance ratio. The scheme performs better as compared to a Quality of Service unicast routing in Mobile Ad hoc Networks.**

Key words — **MANET, Unicast, QoS, Fuzzy logic.**

I. Introduction

Mobile Ad hoc Networks (MANETs) consists of collection of mobile devices like personal digital assistant (PDA), laptops, cell phones etc. Due to limited transmission range, mobile nodes are interconnected by multi-hop wireless links. They are autonomously formed without any pre-configured infrastructure or centralized control [1-2].

Challenges to MANETs include changing network topology, a limited transmission range, and low availability of bandwidth due to wireless environment and consumption of higher control packets for establishing and maintaining. Routing protocols for this kind of wireless network should be able to maintain paths to other nodes and in most cases, must handle changes in paths due to mobility. Unicast routing is used between source and destination in applications like audio/video telephony. The route found between source and destination becomes invalid often because of the dynamic topology of the network. Therefore routing in MANETs is a challenging task [3].

There has been increased demand for multimedia services over MANETs in the recent years. Most of the available routing protocols do not consider the Quality of Service (QoS) problem. QoS is the performance level of a service offered by the network to the user. Most of the multimedia applications have stringent QoS requirements that must be satisfied. The goal of QoS provisioning is to achieve a more deterministic network behavior, so that information carried by the network can be rightly delivered and can be better utilized. However, there still remains a significant challenge to provide QoS routing solutions according to user requirement.

Since QoS parameters are found to be fuzzy in nature, there is no accurate mathematical model to describe QoS routing. Fuzzy logic is used for minimizing uncertainty, imprecision present in the network due to mobility of nodes. Fuzzy logic is a theory that not only supports several inputs, but also exploits the pervasive imprecision information [4]. So adopting fuzzy logic to solve multi metric problems in ad hoc networks is an appropriate choice.

A. *Related works*

Some of the related works for QoS unicast routing in MANETs are as follows: Various unicast routing protocols are described in [5]. The work in [6-7] gives an in-depth study of one-to-many and many to many communications in MANETs and also provides a comparative performance evaluation of MANET routing protocols. A fuzzy controller based QoS routing algorithm with a multiclass scheme (FQRA) in mobile ad hoc networks is given in [8]. The work given in [9] presents QoS routing model in MANETs by using software agents that employ fuzzy logic and neural networks for intelligent routing to support QoS. An intelligent system called "Neuro-Fuzzy" (NF) system is proposed in [10]

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which optimizes the uncertain weights before QoS prediction using Error Back Propagation (EBP) algorithm. Neural network based method for mobility prediction in Ad-Hoc network is presented in [11]. Neural network optimization is done in [12] to improve the performance of Dynamic Source Routing (DSR) protocol by varying the number of layers in it.

B. *Our contributions*

In this paper, we propose a fuzzy based technique for developing a unicast route depending on QoS link parameters like Bandwidth (B), Delay (D) and Reliability (R). These fuzzy parameters together decide the link status as acceptable or not acceptable. Using acceptable links as edges, nodes as vertices we compute the unicast route based on maximum weight attached to the links. Weights for each acceptable link are computed as function of fuzzy parameters. The performance of our model fuzzy based QoS unicast routing in MANETs (FQURM) is compared with QoS unicast routing in MANETs (QURM).

Our contributions in this paper are as follows:
1) Applying fuzzy logic to characterize the quality of links by considering QoS link parameters such as reliability, bandwidth and delays.
2) Developing a QoS unicast route based on fuzzy weights attached to each link.
3) Recomputing fuzzy based unicast route as and when the position of the nodes changes.

The rest of paper is organized as follows: Section II explains proposed work on fuzzy logic based QoS Unicast Routing in MANETs. Section III describes an evaluation of our approach using simulation. Finally, section IV concludes our paper.

II. Proposed work

This section describes network model, fuzzy based QoS unicast routing in MANETs.

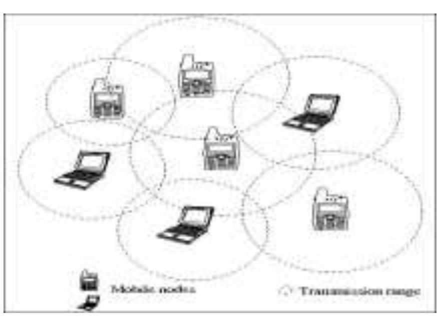

Figure 1. Network Environment

A. *Network Environment*

MANET comprises of several number of mobile nodes which are distributed within a given area as shown in Fig. 1. Each mobile node moves with a different speed in different direction within the given area. Each mobile node has a finite transmission range. The bandwidth, link reliability and link delay at each node is different at different times. The proposed rule is applied at every node. The scheme assumes availability of QoS parameters considered at all the mobile nodes.

B. *Fuzzy based QoS unicast routing scheme*

In this section, we present the fuzzy logic based unicast route development. Fuzzy based model is shown in Fig.2. It comprises of following components: link and connectivity database, fuzzy based unicast route computation and decision maker.

- *Link and connectivity database:* It consists of bandwidth available on link, link realibility, delay between the links, link connectivity information, etc. We consider link bandwidth available, reliability and delays between the links as QoS parameters.
- *Fuzzy logic Unicast Route computation:* It uses link database (B, D, R) and applies fuzzy logic technique to characterize the links.
- *Fuzzy based link decision maker:* It is used to decide whether the link is acceptable or nonacceptable depending on the QoS requirement. It compares the QoS threshold value with output of route computation.

C. *Fuzzy Logic Technique*

Fuzzy logic consists of fuzzifier, fuzzy inference system and defuzzifier blocks as shown in Fig. 3. Each of them is explained below.

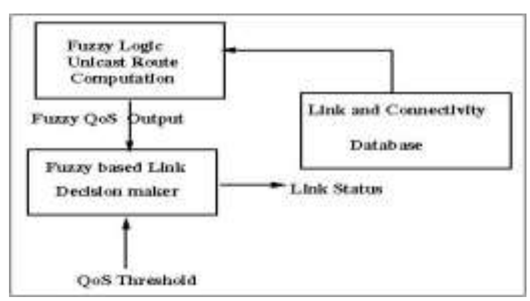

Figure 2. Fuzzy based unicast route at each node

- *Fuzzifier*

In the fuzzification step, a measured value (called crisp input) is converted into linguistic values (such as Low, Medium and High), each of which is represented by fuzzy set. For a given crisp input, the membership function returns a real numbering [0, 1]. The value closer to 1, the more certain the input belongs to the set (eg. more low or less high). A single crisp value can take more than one linguistic value, if the membership values overlap.

The fuzzy parameters considered for QoS are bandwidth of link, link reliability and link delay. The fuzzy based route computation considers a fuzzy set of dimension G(B).G(D).G(R), where G(B) is membership function for bandwidth, G(D) is membership function for link delay and G(R) is membership function for link reliability.

We define the linguistic values for each of the fuzzy variables and associated membership function as shown in Fig.4. The linguistic terms for bandwidth are $B_{Low}(B_L)$, $B_{Medium}(B_M)$, $B_{High}(B_H)$. For link delay it is $D_{Low}(D_L)$, $D_{Medium}(D_M)$, D_{High} (D_H) and for link reliability it is $R_{Low}(R_L)$, $R_{Medium}(R_M)$ and $R_{High}(R_H)$. The membership functions for link delay and reliability are similar to bandwidth.

Bandwidth: For bandwidth, B_n (n^{th} link Bandwidth), its linguistic values are $B_L(b_0$ to $b_2)$, B_M $(b_1$ to $b_3)$ and B_H $(b_2$ to $b_4)$
Delay: For link delays, D_n (n^{th} link), its linguistic values are D_L $(d_0$ to $d_2)$, D_M $(d_1$ to $d_3)$ and D_H $(d_2$ to $d_4)$.
Link reliability: For link reliability, R_n (n^{th} link), its linguistic values are R_L $(r_0$ to $r_2)$, R_M $(r_1$ to $r_3)$ and R_H $(r_2$ to $r_4)$. The membership values are assigned using intuition method. Intuition method is based on the human's own intelligence and understanding to develop the membership functions.

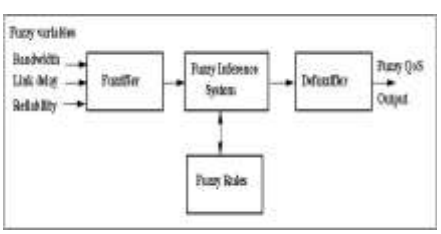

Figure 3. Fuzzy Logic Technique

- *Inference and Defuzzification*

Since there are three linguistic values for fuzzy variables B, D and L, the total number of rules is 27. If the condition is true, we call the rule as acceptable. In our scheme the rule base is in a form called functional fuzzy systems where each rule 'i' is

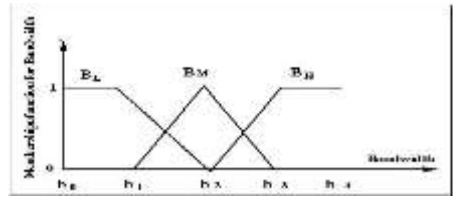

Figure 4. Membership function for Bandwidth

written as follows:

Rule i: If B is B_M and D is D_M and R is R_L
Then

$$n=1,\ W_n=B_n/b_4+D_n/d_0+R_n/r_4) \qquad (1)$$

Where n=1, indicates acceptable link and W_n denotes the link weight. For a rule with non acceptable link, n=0 is used in the rule, and there is no need to compute W_n for such cases. The fuzzy rule base with 27 rules is shown in Table 1.

The defuzzified output parameter will give flexibility to the fuzzy based decision maker to use the best or acceptable links for developing unicast route.

Algorithm:
Begin
1. Assign source and destination node.
2. At each link collect the information about QoS parameters.
3. Apply fyzzy based technique for link status calculation at each node.
4. If link is acceptable, compute weight W_n.
5. Else, go to step 2.

End.

III. Simulation

Simulation is carried out to evaluate the performance of the proposed model. The proposed model has been simulated in various network scenarios on a Pentium-4 machine by using 'C' language. In this section we discuss the simulation inputs, performance parameters and result analysis.

The algorithm is evaluated in terms of the metrics such as QoS acceptance ratio, route discovery time and bandwidth utilization

A. *Simulation Inputs*

Our simulation model is a network of N mobile nodes placed randomly within A X B square meter area. Radio propagation range for each node is T_r meters with mobility of M m/s and channel capacity of B_C Mbps is chosen.

TABLE 1. Fuzzy Rules

Bandwidth (B)	Link Delay(D)	Link Reliability(R)	Link Status
B_H	D_L	R_L	NA
B_H	D_L	R_M	A
B_H	D_L	R_H	A
B_H	D_M	R_L	NA
B_H	D_M	R_M	A
B_H	D_M	R_H	A
B_H	D_H	R_L	NA
B_H	D_H	R_M	NA
B_H	D_H	R_H	NA
B_M	D_L	R_L	NA
B_M	D_L	R_M	A
B_M	D_L	R_H	A
B_M	D_M	R_L	NA
B_M	D_M	R_M	A
B_M	D_M	R_H	A
B_M	D_H	R_L	NA
B_M	D_H	R_M	NA
B_M	D_H	R_H	NA
B_L	D_L	R_L	NA
B_L	D_L	R_M	NA
B_L	D_L	R_H	NA
B_L	D_M	R_L	NA
B_L	D_M	R_M	NA
B_L	D_M	R_H	NA
B_L	D_H	R_L	NA
B_L	D_H	R_M	NA
B_L	D_H	R_H	NA

Link status: A-Acceptable, NA-Not acceptable

Each simulation is executed for S_T seconds of simulation time. To illustrate some results of the simulation, we have to set some parameters for simulation. Some of the parameters considered for simulation are listed in Table 2.

B. *Performance Parameters*

The performance parameters considered in our technique are defined as follows:

TABLE 2. Simulation Parameters

Parameters			Values		
Mobility Model			Random waypoint		
AXB			1000 Sq. meter		
M			5-10 m/s		
N			50		
Distribution of nodes			Random		
B_C			2-10 Mbps		
B_L	B_M	B_H	2-6 Mbps	4-8 Mbps	6-10 Mbps
Delay			0-10 ms		
D_L	D_M	D_H	0-4ms	2-6ms	4-8 ms
Reliability			0-1		
R_L	R_M	R_H	0 - 0.4	0.2-0.6	0.4-0.8
T_r			250 meter		
S_T			600 Seconds		

- *Route Discovery time (RDT):* It is the time taken to find QoS route from source to destination.
- *Bandwidth Utilization:* It is the bandwidth utilized at each mobile to the channel capacity and is expressed in percentage, which also serves as the performance measure for the fuzzy system.
- *QoS Acceptance Ratio:* It is the ratio of number of QoS paths accepted to number of multipath. This is analyzed with number of nodes.

C. *Results*

In this section, we discuss the various results obtained through the simulations. The results include QoS acceptance ratio, route discovery time and bandwidth utilization. Our scheme Fuzzy based QoS Unicast Routing in MANETs is compared with QoS Unicast routing in MANETs without fuzzy logic.

Fig.5 depicts how Route Discovery Time (RDT) varies with number of nodes and varied mobility of 3 m/s, 4 m/s and 5m/s. The RDT increases with increase in number of nodes because of more intermediate nodes between source and destination. RDT of FQURM is less compared to QURM because QURM suffers frequent link breaks and needs route reconstruction frequently which results in increase in RDT.

Fig.6 shows how the QoS acceptance ratio varied with change in number of nodes. Acceptance ratio increases with increase in number of nodes by getting more multipath between source and destination. Acceptance ratio is high in FQURM than QURM with increase in the number of nodes since, more number of intermediate nodes are existing for a connectivity between a pair of hosts.

Fig.7 shows bandwidth utilization vs. number of nodes. It shows that the as the number of nodes increases, the bandwidth utilization reduces. It is due to utilization of bandwidth by each intermediate mobile node.

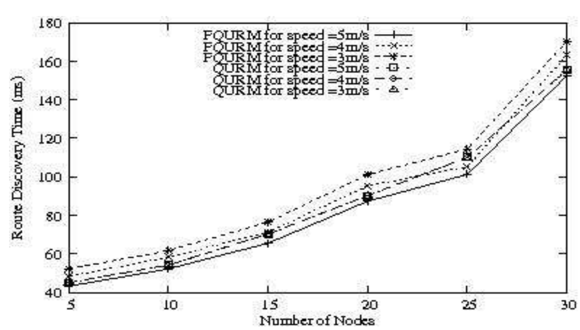

Figure 5. Route discovery time (ms) vs. No. of nodes

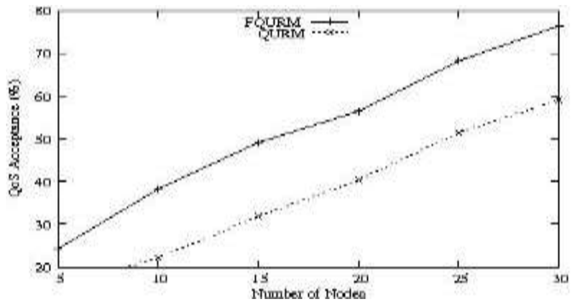

Figure 6. QoS Acceptance ratio (%) vs. No. of nodes

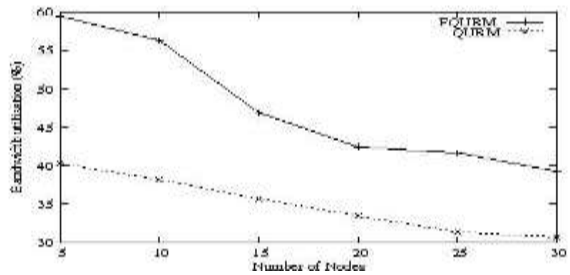

Figure 7. Bandwidth utilization (%) vs. No. of nodes

IV. Conclusions

This paper presented fuzzy based unicast routing in MANETs. Fuzzy rule base is developed to unite the various uncertain QoS parameters such as available bandwidth, link delay, and link reliability which is used for QoS path selection. The results for our proposed FQURM show good QoS acceptance, bandwidth utilization and reduction in route discovery time.

Future work includes optimization of membership function of fuzzy system according to the user QoS requirement, to support QoS routing in MANETs. Also the different parameters like jitter, latency, mobility, battery power can be considered for finding QoS path.

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