A Survey on Fuzzy Based QoS Routing in Mobile Ad Hoc Networks

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***Abstract*—*Mobile Ad Hoc Networks have been deployed in a wide spectrum of domain ranging from military battlefields, natural disaster and manmade disaster management, conference, home networking, patient monitoring, remote landscape monitoring to name a few. MANET being an infrastructureless network with its inherent features like self-configuration, self-organizing and self-administration, it has been focus of research for more than a decade. Due to node mobility, topology of the network changes frequently and rapidly and hence routing is the most challenging functionality in these types of networks. Routing schemes based on various approaches like Bio inspired routing, Secured routing, trust based routing, gossip routing, anonymous routing, fuzzy based routing etc. have been proposed in the literature. Comparing all these approaches fuzzy logic is been proved as a good approach to treat random uncertainty, i.e. the impossibility of prediction of a sequence of events. The main objective of the paper is taking QoS into consideration, based on the fuzzy logic, routing will be done efficiently and effectively.*

Keywords: MANET, Routing, Fuzzy Logic, QoS.

I. INTRODUCTION

Mobile Ad Hoc Networks can be deployed without any pre-existing infrastructure and the group of mobile nodes are connected through wireless links. Nodes receive packets from other nodes and forward them to neighboring nodes, act as hosts as well as routers. Routing protocols developed for MANETs are generally classified into three broad categories: Proactive protocol, Reactive protocol and Hybrid protocols.

A. Proactive Protocols

Proactive protocols are table driven in the sense that all routing decision are made by the nodes based on their pre-determined routes. Every participating node maintains routing information in a routing table. Whenever there is a change in the topology, participating nodes immediately flood the information in the network and all the corresponding nodes in the network update the information in their routing tables. In proactive routing route discovery is easy and route maintenance is hard due to the dynamic topology of the network. Also there is no packet forwarding unnecessarily nodes waste the energy. Destination-Sequenced Distance Vector (DSDV) [1] and Fisheye State Routing (FSR) protocol [2] are some of the most popularly used table-driven protocols.

Proactive protocols take into account only the Least Cost to reach the destination. They fail to consider other important QoS parameters like bandwidth, Jitter, Node Energy Level, Queue Length etc.

B. Reactive Protocols

Reactive protocols are on-demand, in the sense that the routes are discovered when a node desires to send a packet. Two main processes involved are route discovery and route maintenance. The route discovery process is source node broadcasts the route request to its neighbors, which then broadcast the request to their neighbors and so on. Once the route request reaches the destination it sends route reply back to the source. Dynamic Source Routing (DSR) [3] and Ad Hoc On-Demand Distance Vector (AODV) [4] are some of the most popularly used on-demand driven protocols.

This type of protocol takes into account only the Minimum Hop Count to reach the destination. They fail to consider other important QoS parameters like bandwidth, Jitter, Node Energy Level, Queue Length etc.

C. Hybrid Protocols

These protocols incorporate the best features of the Proactive protocols and Reactive protocols. Zone Routing Protocol (ZRP) [5] and Sharp Hybrid Adaptive Routing Protocol (SHARP) [6] are examples for hybrid protocols.

This type of protocols takes into account only the Least Cost and Minimum hop count to reach the destination. They fail to consider other important QoS parameters like bandwidth, Jitter, Node Energy Level, Queue Length etc.

II. WHAT IS FUZZY LOGIC

Figure 1 depicts the structure of a fuzzy logic system [7]. Fuzzy logic system (FLS) basically consists of three major processes namely Fuzzifier, Inference Engine and Defuzzifier. When a crisp input is supplied to a FLS, the

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Inference Engine computes the output set corresponding to each Rule which has IF– THEN structure. The inputs are then combined using the AND operator. The below is an example of rules which explain about the input-output mapping in FLS. IF (Hop Count is ‘‘Minimum’’) AND (Delay is ‘‘low’’) THEN Cost is ‘‘Very Low’’ Rules form the heart of a FLS and may be provided by experts or extracted from numerical data. The IF_PART of a rule is its antecedent and THEN_PART of a rule is its consequent.

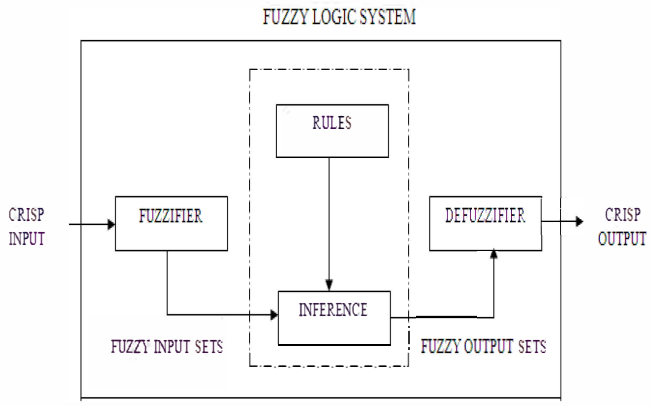

FIG. 1: THE STRUCTURE OF A FUZZY LOGIC SYSTEM

Crisp inputs are made fuzzy by the fuzzification process. There are generally three types of fuzzifiers, which are used for the fuzzification process; they are Singleton Fuzzifier, Gaussian Fuzzifier, and Trapezoidal or Triangular Fuzzifier. Most common type of fuzzification process is the Singleton fuzzification due to its simplicity and speed of computation. Rest of the Fuzzification processes add computational complexity to the inference process. Defuzzification is the last process in a FLS and finds a crisp output value from the fuzzy solution space. Common defuzzification methods are: maximum, mean-of-maxima, centroid, centre-of-sums and centre-of-sets.

III. QOS ROUTING FOR MANETS

A. Quality of Service

QoS is usually defined as a set of service requirements that needs to be met by the network while transporting a packet stream from a source to its destination [8]. To increase the Packet Delivery Ratio and to utilize the network resources in a better and an efficient manner QoS is considered as an important aspect. QoS constraints can be classified as Time Constraints (Delay, jitter), space constraints (system buffer), frequency constraints (system bandwidth) and Reliability constraints (Error rate) [9].

B. Fuzzy based QoS Routing

Already lot of QoS metrics has been proposed for reactive and proactive protocols. To best of our knowledge, none of the existing work has considered all of the QoS constraints. In order to make effective routing decision, Fuzzy logic is incorporated in every node which take the crisp input and generates the corresponding crisp output.

C. QoS Routing in MANETs

In Fuzzy Logic Wireless Multipath Routing FLWMR) [10] single QOS metric i.e. hopcount alone is considered for route selection and packet forwarding. When a source node want to send a message to a destination it floods the route request and finally it reaches the destination node it records the entire path and sends a route reply via that path.

Fuzzy Logic Wireless Load Aware Multipath Routing (FLWLAMR) [10] considers network status as a factor for making routing decisions. Network status ranges from excellent to poor. The fuzzy routing algorithm monitors the congestion status of active routes and provides the feedback i.e. network status to FLC in order to make the effective routing decision. It selects the ‘excellent’ range for data packet forwarding.

The scheme proposed in [11] makes each node to maintain a table to keep the list of the nodes to which it has a connection and the associated bandwidth and delay to reach that neighbor. This table is termed as Neighbor Table. The RREQ packet is extended with three additional parameters: namely min_bandwidth, sum_delay and, min_LET (Link Expiration Time). These extra fields update the available bandwidth, end-to-end delay and LET between the links of a node through the neighbor table of it. Source node broadcasts the route request. When the RREQ packets arrive at the destination node, it accepts all RREQ packets and the FLS available in the destination node calculates the fuzzy cost i.e. bandwidth, end-to-end delay and hops gathered information of network resources. It send back a route reply to the source i.e. the route with minimum fuzzy cost and maximum stability is selected for packet forwarding. The source starts sending the data packet through this path.

A Fuzzy Stochastic Multipath Routing (FSMR) proposed in [12] considers multiple metrics such as hop count, battery power and signal strength. The route selection parameters are energy consumption rate at a node, buffer occupancy rate at a node, link stability between the neighboring nodes and the number of intermediate hops in a route. They calculate the energy levels by transmission, reception and overhearing of packets activities. The congestion status of Manet is also imperative for selecting a reliable routing path. It takes the buffer occupancy rate into account. Link stability parameter helps to select the routes, which are comparatively more stable and long-lived, in order to ensure lower packet loss rate, fewer route failures and less frequent route discovery.

The authors have proposed a multi-objective pareto-optimal technique using Genetic Algorithm (GA) for group communications [13]. Bandwidth, Delay, Jitter, Packet loss rate and blocking property are the five QoS parameters are

considered for their model. The model incorporates a fuzzy-based selection technique for initialization of Quality of Service parameter values at each instance of multicasting.

In [14] the authors have revealed the superiority of generic fuzzy routing over normal routing approach. They have considered only energy consumption rate at a node, buffer occupancy rate at a node, link stability between the neighboring node and number of intermediate hops in a route. The simulation results show that the proposed approach works well in node mobility.

An Entropy based model proposed for supporting route stability in mobile ad hoc networks [15]. Again entropy value has combined with QoS class and fuzzy logic has been applied to route the packet.

Fuzzy scheduler [16] calculates the priority index of each packet, by considering all the inputs which decide the priority associated with the packet. The fuzzy scheduler uses three input variable and one output variable. The three input variables to be fuzzified are the expiry time, and data rate of the packet is associated with. The inputs are fuzzified, implicated, aggregated and defuzzified to get the crisp value of the output i.e., the priority index.

The authors have the scheme that incorporates two fuzzy controllers [17] into each node, fuzzy controller1 has three input metric, no of intermediate nodes, packet queue occupancy and internodes distance. While the fuzzy controller2 has only single input and single output, this predicts the lifetime of the selected route from the source to the destination. Simulation results shows that Packet Deliver Ratio, End-End-Delay and Routing load improving respectively.

A fuzzy logic based algorithm for finding a bandwidth-delay-constrained by Dijkstra's shortest path algorithm proposed in [18]. Bandwidth and delay alone considered as QoS Constraints.

Improved Rank-based Multipath Routing (ImRMR) [19] the authors have proposed a protocol that takes into account of Bandwidth, computing efficiency, power consumption, traffic load and the no of hops as a parameter. Join queries energy consumption, throughput and radio collisions compared with existing protocol ODMRP. It outperforms with the ODMRP.

The authors have considered only Bandwidth and Delay as a dual QoS Constraint [20]. For packet forwarding the packet scheduler is used in the architecture as WRR (Weighted Round Robin). In scheduler queues are served according to a configurable weight that can be changed during network operation. This allows having control of the bandwidth assigned to each service class. The packet delay and discard rate for each queue can be controlled by changing the weight. QoS class 1 is for Application type of the video conference and QoS class 2 is for Application type of the SDTV-Quality Voice. QoS class 3 is for CD-quality audio and QoS class 4 is for Application type of High Quality Voice. It takes into account of the residual bandwidth and traffic class as input and only one output is fuzzy routing decision.

Bandwidth, delay and jitter have considered as a QoS constraints [21]. A flexible QoS multicast routing algorithm based on Artificial Fish Swarm (AFS) algorithm is presented with introduction of principle of fuzzy mathematics. Simulation results shows FAQM performs well for Available bandwidth, Delay and Jitter.

The authors have proposed a fuzzy scheduler [22] which calculates the priority index of each packet. They consider all the inputs which decide the priority associated with the packet. The fuzzy scheduler uses three input variables to be fuzzified are the expiry time and data rate of the packet and length of the nodes to which the packet is associated with. The output variables is the priority index.

IV. QoS Analysis

Approach	*Metrics*	*Remarks*
FLWMR [10]	Hop Count	Fail to consider the Time, Space, Frequency and Reliability Constraints
FLWLAMR [10]	Network status	Satisfies the Space constraint alone
FCMQR [11]	Bandwidth, Delay and Link Expiration Time	Time Constraint alone taken into account
FSMR [12]	Hop count, battery power and signal strength	Hop count, Battery power and Frequency constraints as metric
Multi-objective Pareto-optimal technique using Genetic Algorithm (GA)[13]	Bandwidth, Delay, Jitter, Packet loss rate and Blocking Property	Dual constraints Time and Frequency are taken for consideration
Generic Fuzzy Routing [14]	Energy consumption rate, buffer occupancy and link stability	Energy, Space constraints and link stability taken as metric
Entropy based model [15]	Route stability and Scheduler	Route stability and Priority of packet taken into account
Fuzzy scheduler [16]	Scheduler	Based on the priority, Scheduler transfers the packet

Approach	*Metrics*	*Remarks*
FSRS and FRLP [17]	No of intermediate nodes, queue occupancy and internodes distance	Minimum hop count, internodes distance and Space constraints chosen for consideration
FQRA [18]	Bandwidth and Delay	Time and Frequency constraints as metric
ImRMR [19]	Bandwidth, computing efficiency, power consumption, traffic load and no of hops	Computing efficiency, power consumption, traffic load, no of hops and Frequency constraint for consideration
Multiclass scheme FQRA [20]	Bandwidth, Delay and Scheduler	Time constraint, Frequency constraint and Scheduler taken into account.
FAQM [21]	Bandwidth, Delay and Jitter	Dual constraint Time and space constraint chosen as metric
ESQR [22]	Scheduler	Based on packet priority, packet forwarded to the destination

V. CONCLUSION

This paper discusses about the Fuzzy based QoS routing. The most commonly used QoS parameters are: Bandwidth, Delay, Jitter, Queue, Energy Level and Cost. Few authors have considered Bandwidth, Delay, Jitter and Queue as QoS Constraints. Rest of the authors have taken into account of the Energy Level and Cost as extra parameters. To the best of our knowledge none of the authors has considered all of the QoS parameters. Any QoS aware routing protocol should consider maximum parameters in order to be deployed in real time to offer expected benefits. To fill this gap, this survey has motivated to further the research work considering Bandwidth, Delay, Jitter, Queue, Link Expiration Time and Energy Level into account and develop a new protocol named Fuzzy Cost Based Power Aware QoS Routing Protocol with Mobility Prediction in Mobile Ad Hoc Networks.

REFERENCES

[1] Perkins C, Bhagwat P. Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers. Computer Communications Review 1994; 234-244.

[2] Pei G, Gerla M, Chen T-W. Fisheye State Routing: A Routing Scheme for Ad Hoc Wireless Networks. Proceedings of IEEE Int'l Conf. on Communications (ICC) 2000; 70-74.

[3] Johnson D, Maltz D. Dynamic Source Routing in ad hoc wireless networks. Mobile Computing (edited by Imielinski T, Korth H); Kluwer Academic, 1996; 153-181.

[4] Perkins C, Royer E. Ad-hoc On-Demand Distance Vector Routing. Proceedings of 2nd IEEE Workshop on Mobile Computing Systems and Applications 1999.

[5] Z. Haas and M. Pearlman, "Determining the Optimal Configuration for the Zone Routing Protocol", IEEE JSAC, Special Issue on Ad-Hoc Networks, August 1999.

[6] Venugopalan Ramasubramanian, Zygmunt J. Haas and Emin Gun Sirer, "SHARP: A Hybrid Adaptive Routing Protocol for Mobile Ad Hoc Networks", MobiHoc'03, June 1–3, 2003, Maryland, USA.

[7] E.H. Mamdani and S.Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller", International Journal of Man-Machine Studies, 7(1):1-13, 1975.

[8] Prasant Mohapatra, Jian Li and Chao Gui, University of California, "QoS in Mobile Ad hoc Networks", IEEE Wireless Communications June 2003 Pages 44–52.

[9] Aura Ganz, "Quality Of Service Provision In Mobile Ad Hoc Networks" For TACOM Seminar January 14, 2002 by University of Massachusetts, Amherst.

[10] Alandjani Gasim, Johnson Eric E. In: Fuzzy routing in ad hoc networks, performance, computing, and communications conference 2003. IEEE international volume, issue, and 9–11 April 2003. p. 525–30.

[11] G. Santhi, Alamelu Nachiappan: Fuzzy-cost based multi-constrained QoS routing with mobility prediction in MANETs, Egyptian Informatics Journal (2012) 13, pp. 19–25.

[12] Rajiv V. Dharaskare, M.M.Goswami: Intelligent Multipath Routing Protocol For Mobile Ad Hoc Network, International Journal of computer science and Applications Vol.2, November / December 2009, pp. 135–145.

[13] Satyananda Champati Rai, Bijan Bihari Misra, Ajit Kumar Nayak, Rajib Mall, Sateesh Kumar Pradhan: A Multi-Objective QoS Optimization with Fuzzy Based Parameter Setting for Real-Time Multicasting, Int. J. Communications, Network and System Sciences, 2010, 3, 530-539.

[14] Hui Liu, Jie Li, Yan-Qing Zhang and Yi Pan: An Adaptive Genetic Fuzzy Multi-path Routing Protocol for Wireless Ad-Hoc Networks, International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing and First ACIS International Workshop on Self-Assembling Wireless Networks (SNPD/ SAWN'05), 2005, 468–475.

[15] GUI Chao: An entropy-based stability QoS routing with priority scheduler in MANET using fuzzy controllers, Journal of Communication and Computer, Mar. 2007, Volume 4, No. 3 (Serial No. 28), 52–54.

[16] Shangchao Pi1, Baolin Sun2: Fuzzy Controllers Based Multipath Routing Algorithm in MANET, on Applied Physics and Industrial Engineering Conference, Physics procedia 24 (2012), 1178–1185.

[17] Taqwa Odey, Abduladhem A. Ali: Fuzzy Controller Based Stable Routes with Lifetime Prediction in MANETs, International Journal of Computer Networks (IJCN), Volume (3): Issue (1): 2011, 37–42.

[18] M. Yaghmaei, M. Baradaran, H. Talebian: A Fuzzy QoS Routing Algorithm for Communication Networks, Communication Systems conference 2006, IEEE, 1–5.

[19] A Naga Raju, Dr S. Rmachandram: Fuzzy Cost Based Multipath Routing for Mobile Ad-hoc Networks, Journal of Theoretical and Applied Information Technology, 319–326.

[20] B. Sun, C. Gui, Q. Zhang, H. Chen: Fuzzy Controller Based QoS Routing Algorithm with a Multiclass Scheme for MANET, Int. J. of Computers, Communications and Control, ISSN 1841-9836, E-ISSN 1841-9844 Vol. IV (2009), No. 4, pp. 427-438.

[21] Junwei Wang Zhaoxia Wu: A Fuzzy Decision Based Intelligent QoS Multicast Routing Algorithm, Automation and Logistics Conference, Chongqing, China, August 2011, 169–172.

[22] ChunHua Xia: An Entropy-Based Stability QoS Routing with Priority Scheduler in MANET, Wireless Communications Networking and Mobile Computing (WiCOM), Conference on Date: 23-25 Sept. 2010, 1–3.