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Fuzzy Logic based Multicast Routing Protocol in MANET

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***Abstract*- In a mobile ad hoc network (MANET), providing a reliable and stable route between nodes is very challenging and critical. This paper proposes a crosslayer based multicast routing and rate control for MANET that provides a high stable route to the destination. In our previous work implemented cross layer based routing and rate control for a unicast routing protocol. In this extension work, we implemented in the multicast routing protocol. In traditional protocol uses sequence number and hop counts only taken as a parameter to select a path between sources to a destination. The proposed protocol uses multiple parameters like route stability and bandwidth. The route stability is estimated based on available battery power, distance and link quality. Source node uses fuzzy rules and fuzzification process to select an optimal path from two parameters. Simulation results demonstrate that how the fuzzy logic and fuzzification process involved in packet loss, delay and delivery ratio.**

Keywords: Fuzzy Logic, Unicast, Multicast, Fuzzification, and Defuzzification.

I. INTRODUCTION

A MANET is a set of mobile nodes operating without any infrastructure network and the assistance of base stations. Mobile hosts can communicate each other directly if they are within transmission range otherwise indirectly by relaying by intermediate mobile nodes [1].The main characteristics of mobile nodes are low bandwidth, mobility, and low power. It is used where rapid deployment and dynamic configurations are necessary (Battle fields, emergency search and rescue site, Class rooms and convention hall, etc.).These applications use multicast operations. In ad hoc network, it is more difficult to reduce the transmission power and overhead. Multicasting can enrich the efficiency of the wireless link when sending multiple copies of messages by broadcasting techniques. Multicasting is also faced some challenges such as Difficult in multicast packet forwarding, group membership management and maintenance of multicast structure in the dynamic network topology [2].

A. Multicast protocols in MANET

The traditional multicast approaches in wired network not suitable for MANET. Because nodes in MANET moves arbitrarily, network infrastructure changes frequently and bandwidth and battery power is limited. These constraints in network infrastructure make multicasting in mobile ad hoc network are a big challenge. Some protocols solve the problems dynamically build routes and maintain membership etc. In this section, we discuss multicast routing protocols in mobile ad hoc network. [2]

Multicasting routing protocols are classified into following ways

1. Tree-based multicast routing protocol
2. Mesh-based multicast routing protocol
3. Hybrid multicast routing protocol

In tree based multicasting, network topology dynamically changing due to the mobility of mobile nodes in ad hoc network. This protocol needs frequent reconfiguration [3]. A tree-based multicast routing method establishes and maintains a shared multicast routing tree to deliver data from a source to destination receivers of a multicast group. It is divided into source rooted and core rooted multicasting protocols. When source-rooted tree-based multicast routing protocols used in the dynamic network, it suffers from high traffic overhead.Because source node to be aware of the topology information and addresses of all its receivers in the multicast group.

II. CROSS-LAYER DESIGN

Traditional OSI model layered architectures are not suitable for the mobile ad hoc network; because the open system interconnection model divides the overall networking task into seven layers and defines a hierarchy of services to be provided by separate layers. The OSI traditional model blocks direct communication between nonadjacent layers; contact between adjacent layers is a limited and systematic approach to procedure calls and responses. Cross-layer design violates the traditional architecture based on three reasons, the unique problems created by mobile ad hoc network links, the possibility of opportunistic communication on wireless mobile ad hoc network links, and the new mode of communication offered by the wireless medium. In a different manner layered architecture is violated, they are the creation of new interfaces between layers, merging of adjacent layers, design coupling without new interfaces and vertical calibration across layers.

Creation of new interfaces category is divided into subcategories depending upon the direction of information flow they are upward information flow, downward information flow and back and forth information flow. The merging of adjacent layers creates a super layer, the service provided by super layer is the union of service provided by adjacent layers. Design coupling without new interfaces category of cross-layer design involves coupling two or more layers without creating any additional interfaces for information sharing at runtime. Vertical calibration across layers collects various parameters across layers. The cross-layer interactions divided into three categories direct communication between layers, a common database across layers and entirely new abstractions [4][5]. A cross-layer approach to MANET design enhances the performance of a system by jointly designing multiple protocol layers [6].

III FUZZY LOGIC IN MANET

A. Fuzzy controller

Route selection process is a very sensitive and important activity for the mobile ad-hoc network (MANET).Ranking of multiple routes from the source node to the destination node can result in efficient route selection can provide many other benefits for better performance of MANET [7].The best route selection can improve the quality of service, end to end delay and throughput. MANETs are power constrained since nodes operate with limited battery energy and reduce the life-time of the node. To increase and maximize the lifetime of the ad hoc networks, transactions through mobile nodes must be controlled [8].In MANET fuzzy logic is used to make the accurate decision in route selection using available parameters such as battery power, available bandwidth, distance and stability of the route. It minimizes the overall setup time required for establishing a connection[9].The fuzzy control system consists of fuzzifier, fuzzy knowledge base, rule-based decision and defuzzifier for determining control actions using fuzzy logic reasoning. Since the inputs and outputs of the systems are commonly crisp value in nature, fuzzification and defuzzification process is used to translate them to and from fuzzy representation.

Fuzzification

It is a process where crisp input values represented in terms of the different membership function, of the fuzzy sets.

Fuzzy Inference Engine

After the fuzzification process, the inference engine determines the fuzzy output using fuzzy logic. It is a system that uses fuzzy rules that are in the form of if-then rules to map a set of crisp input values to set of fuzzy output values.

De-fuzzification

Defuzzification process then used to translate the fuzzy output to a crisp value. Various methods used in defuzzification process.It is a mathematical process used to convert the fuzzy output to a crisp value.

IV RELATED WORK

Narayanan, S and Rani Thottungal [10] have proposed cross-layer based routing and rate control using fuzzy decision systems in MANET. This protocol uses fuzzy logic system1 to select a route in source and fuzzy logic system2 in a destination to monitor the data packet transmission. In a selection of a route to the destination, source node performs the fuzzy-based optimal path selection by considering the parameters such as battery power, distance, and bandwidth. The path stability is estimated based on available battery power, distance and link quality. Source node uses nine fuzzy rules to select an optimal path from two parameters. To adjust a data rate from the destination node, it uses fuzzy logic system2 and takes the parameters packet loss ratio and an end to end delay. Destination node uses nine fuzzy rules to adjust the data transmission rate of the source. This result minimizes the end to end delay and packet loss rate.

Narayanan, S and Rani Thottungal [11] have proposed a cross-layer based routing with power aware rate adjustment that is an extension of their previous work. This protocol is also uses two fuzzy logic systems FLS1 and FLS2.Fuzzy logic system1 is applied in source node to select the best path based on the parameters path stability, residual bandwidth, and residual energy. It uses fifteen fuzzy rules to select an optimal path. After selecting the path, source node estimates the initial transmission power, physical data rate, and power consumption ratio to construct a transmission power and rate table. Fuzzy logic system2 is applied in destination node to adjust a data rate based on a delay and packet loss ratio. The physical data rate of the source is adjusted by comparing the transmission power and rate table. This protocol minimizes the energy consumption and increases the throughput.

Mala Chelliah et al. [12] have proposed fuzzy multi-constraint AODV routing technique to make a routing decision based on more than on constraint. Source node to discover a new route sends RREQ packets. Intermediate nodes on the path measure the constraints buffer occupancy, residual energy and hop count to apply fuzzy logic. Source node collects all RREP. Then compares the value of fuzzy grade that is available in the route table. Then decides the route and updates the routing table. This technique minimizes the routing overhead and maximizes the throughput

Arashdana and Mohamed Hadibabaei[13] have proposed a fuzzy based stable routing algorithm to increase the reliability during route selection and for route maintenance before breaking packet transmitted path.Source node determines the link stability coefficient between nodes based on the parameters node position and velocity information.Fuzzy logic applied to calculate the link stability coefficient (LSC) and calculates the route stability coefficient(RSC) between source and destination using all link stability coefficients in RREP message. In route maintenance, the degree of route stability is calculated based on neighbor nodes distance and relative velocity.When the destination receives bath breaking warning, it broadcast the RREC message. Source node calculates RSC and compares the RSCs and change the data transmit packet path, it reducing initiate route recovery time. In the protocol, all routes LSCs and RSCs calculated and updated in the route table, the alternate route taken from the table. This algorithm improves the route stability and network performance effectively.

Alireza Shams Shafigh et al. [14] proposed fuzzy logic based on demand multicast routing protocols in MANET that is mesh-based multicast routing. This algorithm handles imperfect information in ODMRP route selection process and establishes a strong forward group that leads to higher stability delivery structure. It changes join query packet to get information about nodes and classify weak and strong nodes. Based on the available bandwidth, loss rate experienced, moving speed and power level, Fuzzy inference system classifies strong nodes and small nodes. The node that has the high power level, high bandwidth availability, low loss rate and low moving speed is called strong node. A strong node forms the forwarding group. Through the high probability, strong nodes packet is cached and forwarded. This proposed method increases the packet delivery rate, reducing end to end delay and consumed power.

P. I. Basarkod and Sunilkumar S. Manvi [15] proposed an on-demand QoS and stability based multicast routing that is an enhancement of ad hoc on demand multicast routing to provide stable connection and support for real-time applications. They utilized the node's following parameters link stability, delay and bandwidth in route discovery process for providing an efficient and low overhead QoS. Proposed protocol reduces the packet overhead, an end to end delay and improves the packet delivery ratio.

Yufang and Thomas Kunz [16] proposed a tree-based multicast routing protocol MAODV. It creates routes on-demand to the destination. Route discovery is based on an RREQ and route reply RREP. When a multicast source requires a route to a multicast group, it broadcasts an RREQ packet with the join flag (RREQ-J) and the destination address set to the multicast group address. A member of the multicast tree with a current route to the destination responds to the request with an RREP packet. Nonmembers rebroadcast the RREQ packet. Each node on receiving the Route Request Message(RREQ) updates its multicast route table. The route table contains the sequence number and next hop information to the source node. This information is used to route reply back to the source. If the node of origin receives multiple repliesRREP for its route request, it select the path based on fresh sequence number or the least hop count. It then sends a multicast activation message MACT, that is used to activate the route from the source node to the node sending the reply. If a source does not receive an MACT message within a certain period, it broadcasts another RREQ-J. After a certain number of retries declares itself the Group Leader. The group leader handles periodically broadcasting group hello (GPRH) messages to maintain group connectivity.

V. ESTIMATION OF METRICS

A. *Bandwidth estimation*

In a MANET nodes that want to send the data has to collect of its local bandwidth available and information about neighbors within the radio transmission range. The sender node pays attention to the channel and estimates local bandwidth (BWlo) because the bandwidth is shared between neighboring nodes. It depends on the ratio of idle time and busy period for a predefined interval. [17]

BWlo= * (Tid/ Ttot) (1)

Where C= Channel capacity

Tid = Idle time period

Then sender node collects the minimum available bandwidth (BWmin) of all the nodes within the interference range. The residual bandwidth is calculated based on minimum bandwidth and local bandwidth of the node.

BWre = BWlo - BWmin (2)

BWre=Residual bandwidth

BWlo=local bandwidth

BWmin=Minimum available bandwidth

B. *Estimation of Route Stability*

The route stability is calculated by considering the parameters such as available battery power, distance, and route quality (shown in equation (3)). These values retrieved dynamically from PHY and MAC layers. [18]

$$\text{Route Stability (RS)} = \left(\frac{P_{ij} * RQ_{ij}}{D_{ij}} \right) \qquad (3)$$

The parameters shown in the above equation are illustrated below

Available Battery power (Pij): It is defined as the ratio of power received at the node (Prx) to the power transmitted (Ptx) by the neighbor node.

Route quality RQij: It measured in terms of expected transmission time (ETT).

The expected transmission time (ETT) for a single route is defined as the expected time to send a data packet at the MAC layer (Illustrated using Eq: 5). ETT route metric can be obtained by summing all ETT values of the individual links in the route.

ETT = ETX * (k/BWc) (4)

Where k = average size of a packet

BWc = current link bandwidth

ETX = Expected transmission count metric

The expected transmission count metric (ETX) is the measure of link and route quality. ETX metric for a single route is defined using Eq 6

$$\text{ETX} = \frac{1}{(Pkt_{tx} * Pkt_{rx})} \qquad (5)$$

Where Pkttx = successful packet delivery probability in the forward direction.

Pktrx = successful acknowledgment packet reception probability.

Distance Dij: The distance among the two nodes is computed using the free space propagation model.

C. Estimation of End to End delay

The delay comprises of all possible delays such as buffering caused during route discovery process, queuing at the interface queue, resend delay at the MAC, propagation and transmission time. Thus, it is defined as the time taken for transmission of data from source to destination.[19]

DE-E = (Tdrx –Tdtx)

Where Tdrx = data reception time

Tdtx =data transmission time.

D. Estimation of Packet loss ratio (PLR)

It is defined as the number of data packets that are not effectively transmitted to the destination. It is expressed in terms of dropped packets.

VI PROPOSED TECHNIQUE

A. Algorithm for optimal path selection

1. When node wishes to join a group or send to message to multicast group it checks the available route, then goto step10
2. If not broadcast the route request join message through intermediate nodes.
3. If an intermediate node is not a member of that group, or it does not have a path to that group, it rebroadcasts the Route request to its neighbors.
4. Intermediate nodes set up pointers to establish the reverse route in their route tables
5. If a node receives an RREQ-Join for a multicast group, the node may reply if it is a member, and its recorded sequence number for the multicast group is at least as great as that contained in the RREQ.
6. The reply node updates its route information and multicast route tables.
7. As nodes along the route to the source node S receive the RREP, updates the route cache about the source, destination, previous hop node, battery power, link quality and available bandwidth.
8. When S broadcasts an RREQ for a multicast group, it often receives more than one reply. S then computes path stability and bandwidth based on the collected information from RREP.
9. The values computed by S in step 8 are considered as inputs for the fuzzy logic system. Based on the result, Source selects an optimal route that has high link stability and bandwidth value. This optimal route used for data transmission between the source and the destination.
10. The path available in the route cache is considered for data transmission.

B. Fuzzification:

This process involves fuzzification of input variables such as PS and BWres. The crisp inputs are taken from these variables, and these inputs are given a degree to appropriate fuzzy sets. The crisp inputs are a combination of PS (say S) and BWres (say B). We take three possibilities, high, medium, and low for S and B. Bandwidth (residual), and Path stability are given as inputs and the output represents the optimal path (OP) for data transmission.

The fuzzy sets are defined with the combinations presented here.

1. If Bandwidth is low, and Route Stability is low
   Then optimal path is very low
2. If Bandwidth is low and, Route Stability is medium
   Then optimal path is low
3. If Bandwidth is low and, Route Stability is high
   Then optimal path is low
4. If Bandwidth is medium and, Route Stability is low
   Then optimal path is medium
5. If Bandwidth is medium and, Route Stability is medium
   Then optimal path is very medium
6. If Bandwidth is medium and, Route Stability is high
   Then optimal path is high
7. If Bandwidth is high and, Route Stability is low
   Then optimal path is high
8. If Bandwidth is high and, Route Stability is medium
   ` Then optimal path is high
9. If Bandwidth is high and, Route Stability is high
   Then optimal path is very high

This above rule illustrates the function of the fuzzy logic system.

C Defuzzification

The process by which a crisp value is extracted from a fuzzy set as a representation value referred to as defuzzification. The centroid of the area is taken into consideration for defuzzification during the fuzzy decision-making process. The formula (5) describes the defuzzifier method.

$$Fuzzy\_cost = [\sum_{allrules} z_i * \lambda(z_i)] / [\sum_{allrules} \lambda(z_i)]$$

Where fuzzy cost is used to identify the degree of decision making, zi is the fuzzy all rules, and variable and (zi) is its membership function. The output of the fuzzy cost function is modified to crisp value as per this defuzzification method. [20]

Thus, the chosen optimal path is utilized for transmission of data from source to destination.

D Optimal rate adjustment

The source proceeds with the transmission of data to the destination through the selected optimal path at this moment, at the receiver side, the destination node computes the parameters such as end-to-end delay (D_{E-E}) and packet loss ratio (PLR) .It applies these inputs to FLS in order to estimate the state of transmission rate (R_{tx}).

The fuzzy sets are defined with the combinations presented here

1. If delay is low, and path loss ratio is low
   Then output is very high
2. If delay is low, and path loss ratio is medium
   Then output is high
3. If delay is low, and path loss ratio is high
   Then output is low
4. If delay is medium, and path loss ratio is low
   Then output is medium

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5. If delay is medium, and path loss ratio is medium
   Then output is medium
6. If delay is medium, and path loss ratio high
   Then output is low
7. If delay is high, and path loss ratio low
   Then output is low
8. If delay is high, and path loss ratio medium
   Then output is low
9. If delay is high, and path loss ratio high
   Then output is very low

The obtained output value is defuzzified similar to section VI.C. As an outcome of fuzzy decision, we can obtain the state of transmission rate. The current transmission rate of the source is adjusted by comparing the output of FLS2 with initial transmission rate of path. This process prevents the congestion.

VII SIMULATION RESULTS

The performance of Cross-layer based Multicast Routing and Rate Control (CBRRC-MULTICAST) technique is evaluated through NS2 [25] simulation. A random network deployed in an area of 1000 X 1000 m is considered. The sink is assumed to be situated 100 meters away from the above specified area. In the simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. The simulated traffic is CBR with UDP source and sink. The number of sources is fixed as 4 around a phenomenon. Table 1 summarizes the simulation parameters used

No. of Nodes	50,75,100,125,150
Area Size	1000 X 1000
Mac	802.11
Routing protocol	FBRRT
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512 bytes
Rate	100kb
Transmission Range	150m
Speed of events	5 m/s
Pause time	5,10,15,20 and 25 sec.
Flows	2,4,6 and 8

Table 1: Simulation Parameters

A Unicast protocol

The table shows that when the parameters pause time (5) and a number of nodes (50) are constant, and packet flow is 2,4,6,8 its packet drop, delay, delivery ratio and overhead is changed. When the number of flow is 2, it reduces the packet drop, delay, and over the head. It increases the delivery ratio. When increasing the number of data flow, packet drop and delay are increased. Its delivery ratio decreased.

No of flows	Pkt received	Pkt dropped	Delay in s	Delivery ratio %
2	2190	189	0.6534	93.39
4	2222	3199	13.5636	47.39
6	2558	5084	16.7557	36.37
8	2713	7642	19.1104	28.93

Table 1-Based on Flows

No of nodes	Pkt received	Pkt dropped	Delay in s	Delivery ratio %
50	2190	189	0.6559	93.39
75	2242	501	0.8023	95.60
100	2345	01	0.0149	100
125	2009	383	5.689	85.67
150	1424	1731	10.505	60.72

Table 2-Based on nodes

In this simulation, pause time (5) and a number of flows (2) are constant. The number of nodes changed like 50, 75, 100, 125 and 150.When increasing the number of nodes up to 75 packet drops, delay delivery ratio increased. At 100 nodes packet drop is the minimum delay is very low delivery ratio is increased. Above 100 nodes packet drop, the delay is increased, and delivery ratio decreased. In all the nodes, simulation number of overhead is decreased.

Pause time	Pkt received	pkt dropped	Delay in s	Delivery ratio %
5	2190	189	0.6534	93.39
10	1891	742	3.2872	80.64
15	1575	816	8.3738	67.16
20	1699	866	10.5819	72.45
25	1956	641	2.94609	83.41

Table 3- Based on pause time

In this simulation, pause time increases from 5 to 25 when numbering of nodes (50) and a number of flows (2) are constant. This result shows that packet drops, delivery ratios, over heads and delays go up and down.

B Multicasting protocols

No of receivers	Packet received	Packet dropped	Delay in s	Delivery ratio %
2	2344	11	0.0509	99.95
4	3900	815	5.7922	83.17
6	4983	2100	6.8269	70.85
8	4356	5086	14.1348	45.41

Table 4- Based on number of receivers

When the increasing number of receivers packet drop, the delay is increased, and delivery ratio continuously decreased. During this simulation number of nodes, 50 and pause time is 5.

No of nodes	Pkt received	Pkt dropped	Delay in s	Delivery ratio %
50	4356	5086	14.1348	45.41
75	2776	7317	17.2841	29.60
100	2431	7311	17.263	25.51
125	5863	3573	10.5372	63.25
150	1816	8015	21.3273	19.36

Table 5-Based on nodes

Here pause time (5) and a number of receivers (8) are fixed. After the 50 nodes and 8 receivers packet sending is constant when the number of nodes increased to 75,100 the packet drop, the delay is increased, and delivery ratio decreased.At the time of a number of nodes 125 packet drop, delay decreased and delivery ratio increased. When the number of nodes increased to 150 packet drop increased more than previous packet drops, delay and delivery ratio decreased.

Pause time	Pkt received	Pkt dropped	Delay in s	Delivery ratio %
5	4356	5086	14.1348	45.41
10	3974	5350	13.4551	42.38
15	3236	6331	15.2291	34.51
20	2037	7415	19.0803	21.72
25	3853	5713	14.0627	41.08

Table 6-based on pause time

In this scenario only pause time is changed the number of nodes (50), and a number of receivers (8) are constant.Up to pause time 20 packet drop, delay continuously increasing and delivery ratio decreasing. When pause time is 25 packet drops, delay decreased, and delivery ratio decreased.

CONCLUSIONS

In this paper, we have implemented cross layer based multicasting routing and rate control protocol. The fuzzy logic system1 takes the values route stability and bandwidth for its fuzzification process and then decides the optimal route to the destination. The fuzzy logic system2 takes the values delay and path loss ratio to adjust the transmission rate.In this simulation multicasting, routing protocol increases packet loss and delay than unicasting protocols.

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