CROSS LAYER BASED MULTICAST ROUTING PROTOCOL USING FUZZY DECISION SYSTEM IN MOBILE AD HOC NETWORK

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Abstract

In a mobile ad hoc network (MANET), due to dynamic network topology providing a reliable and high stability route between communication nodes is very challenging and critical. This paper proposes a cross-layer based multicast routing protocol for MANET that provides a high stable route to the destination. In our previous work, we implemented fuzzy based cross-layer routing in MANET for a unicast routing. In this extension work, we implemented fuzzy based cross-layer multicast routing protocol. In traditional MAODV 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, bandwidth to select the optimal route.
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 to destinations. Our protocol performance is compared with PDTMRP protocol. Simulation results show that our protocol reduces delay, drop, packet loss ratio and increases delivery ratio.

**Key Words**: Fuzzy Logic; Route Stability; Multicast; Fuzzification; Defuzzification

1 **Introduction**

A mobile ad hoc network is a set of mobile nodes that sharing information without any aid of established infrastructure. Operating with dynamic mobile nodes and self-organize to form a radio network links. Mobile nodes communicate each other directly if they are within communication range otherwise indirectly through intermediate mobile nodes [1]. Due to channel dynamics and infrastructure less network it faces more challenges. These networks used where an infrastructure establishment for communication is too expensive to deploy, rapid deployment and dynamic configurations are necessary [2]. MANET has more popular in recent research and also have more challenges such as capacity constraint, unreliable communication medium, unpredictable channel access delay, and inaccurate bandwidth estimation. It has some limitations in the network and dynamic topology, the absence of centralized QoS control, network heterogeneity, and limited battery power. It is used in disaster management, tactical networks, wireless networks and data networks. Multicasting can enrich the efficiency of the MANET when sending multiple copies of messages by broadcasting techniques. Multicasting technique has also faced some challenges such as Difficult in group membership management, forwarding the multicast packet and maintenance of multicast structure over the dynamic network topology [3].

The wired network multicast routing protocols are not suitable for mobile ad-hoc network multicasting technique because nodes in MANET moves arbitrarily, network infrastructure changes dynamically, bandwidth and battery power is limited. These constraints make big challenges to multicast routing in the MANET. In this
following section, we discuss multicast routing protocols in mobile ad hoc network. [4]

Multicasting routing protocols are classified into following ways
Based on construction of distributed paths
1. Tree-based multicast routing protocol.
3. Hybrid Based Multicast routing protocol.

Based on acquisition and maintaining routing information
1. Proactive multicast routing protocol
2. Reactive multicast routing protocol

Based on establishment of multicast connectivity
1. Source initiated multicast routing protocol
2. Receiver initiated multicast routing protocol

Based on maintenance of multicast group
1. Soft state multicast routing protocol

2 Cross-Layer Design

Traditional layered protocol stacks used in all modern communication systems but not suitable for mobile ad hoc network. The seven layer architecture divides the overall networking task into layers each layer having separate services in hierarchical order and blocks direct communication between nonadjacent layers. It faces more challenges to improve the quality of services and to propagate the data to more receivers. The cross-layer design framework enhances the performances of a node by violating the layered architecture. It allows interaction among multiple layers for improving system
performance. Information exchange takes place between lower layers, network layer, and transport layer. Nodes different parameters controlled in distinct layers in ad hoc network. In cross-layer design framework link layer and physical layer parameters signal to noise ratio and interference level involved in route selection process in the network layer. The cross-layer design improves the quality of service.

Fig-1 The above cross-layer framework explains the potential interaction among layers. [6][7][8]

3 Fuzzy Logic in MANET

3.1 Fuzzy Inference System

Fuzzy inference system actions were determined by fuzzy logic rules. Its inputs and outputs are crisp in nature fuzzification, and defuzzification process is needed to translate crisp values to and from fuzzy representation. [9]
Fuzzifier

It gets the two or more crisp parameter as input and converts the crisp parameters into fuzzy membership function that values between 0 to 1. The shape of the function may be triangle or trapezoid based on the number of points to define one member function.

Fuzzy decision-making system

This system contains the set of fuzzy rules that is IF-THEN rules. Based on the rules framed in the system determines the fuzzy output. The number of rules can change based on the number of membership function used to decide the result.

De-fuzzifier

It is then used to translate the fuzzy output to a crisp value. For defuzzification process various mathematical methods used in which most popular method is the center of gravity method.

Knowledge base

In fuzzy inference system, the relationship between crisp input and output parameters defined by the knowledge base. From a practical consideration, each input and output variable are characterized by the following items in the knowledge base:

- Its universe, the domain over which the variable can assume values
- The set of linguistic attributes (labels) that compose its qualitative representation
- For each label, the membership functions defining it
4 Related Work

Alireza Shams Shafigh et al. [10] 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 strong nodes have properties like high power level, and bandwidth availability, low loss rate and moving speed. Strong nodes form a strong 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.

Narayanan, S and Rani Thottungal [11] have proposed cross-layer based unicast 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. To select an optimal route to the destination, source node performs the fuzzy-based optimal path selection process 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 system 2 and takes the parameters end to end delay and packet loss ratio. 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.

Ravi Prasad. B et al. [12] have proposed fuzzy improved adaptive delay routing protocol to select a route to the destination. Intermediate nodes in the forward direction collect the information about previous nodes bandwidth, speed, and power and loss rate in ROUTE REQ packet. Based on the parameters, every node in mesh network applies fuzzy logic to find the nodes probability of caching and forwarding. Based on the probability of caching and forwarding information intermediate node classify the nodes into
low, medium and high probability and store the information in ROUTE REQ packet then source node selects the strong forwarding group. This method leads to decrease the resource consumption and higher stability. It reduces the over head, end to end delay, power consumption and increase the packet delivery ratio.

Shanthi G and Alamelu Nachiappan[13] have proposed the fuzzy cost based multi-constrained routing protocol to select an optimal path to the destination in multicast routing by considering multiple independent metrics such as bandwidth, end-to-end delay, and a number of intermediate hops. In this method, all the nodes apply fuzzy logic to solve the multi metric problem. Using fuzzy logic this protocol uses mobile predicting mechanism to chooses the most stable path that satisfies the multiple Quality of service constraints with minimum fuzzy cost and maximum path stability. This protocol increases packet delivery ratio, and path success ratio and reduces delay.

SujathaV. Mallapur and Siddarama R Patil [14] have presented fuzzy logic based trusted candidate selection for stable multipath routing in mobile ad hoc network. This protocol provides reliable and stable quality path between nodes. It uses two phases, in the first phase during route request it takes the parameters bandwidth, node mobility, node energy, and link quality and reputation index metrics. Then apply fuzzy logic to select efficient nodes from the network that is called candidate node having special properties. In the second phase, it constructs routing backbone in which multiple paths established between sources to the destination node. This is because if candidate node is fail due to bandwidth, residual energy an alternate path is selected for transmission before path fails. This protocol provides more security, increases packet delivery ratio and reduces packet drop and delay.

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 nodes 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 replies RREP for its route request, it selects 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.

5 Cross-Layer Based Multicast Routing

In this section, we explain parameters used for the cross-layer based multicast route selection process. Fuzzy logic system available in nodes that are responsible for best route selection. In Fuzzy Logic System, the nodes obtain the input parameters such as route stability and residual bandwidth through route discovery mechanism. These inputs are fuzzified and defuzzified to obtain the optimal path for data transmission. Estimation of parameters explained in following sections.

5.1 Bandwidth estimation

The Node that want to transmit the data calculates its local bandwidth and neighbors bandwidth information within the communication range. Because bandwidth is shared between neighboring
nodes, the node pays attention to the channel and estimates local bandwidth (BWloc). It depends on the ratio of channel idle time period and channel busy time period for a predefined interval. [17]

\[ BWloc = C \times \left( \frac{T_{id}}{T_{tot}} \right) \]  
(1)

Where \( C \) = Channel capacity  
\( T_{id} \) = Channel idle time period

The difference among BWmin and BWloc gives the residual bandwidth (BWres) of the node.

\[ BW_{re} = BW_{loc} - BW_{min} \]  
(II)

BWmin - Minimum available bandwidth of all the nodes within the interference range.

5.2 Estimation of Route Stability

In this process, available battery power, distance, and route quality values retrieved dynamically from PHY and MAC layers. Route stability is calculated based on the above-identified parameters [18]

Route Stability \( RS = \left( \frac{P_{ij} \times RQ_{ij}}{D_{ij}} \right) \)  
(III)

Available battery power \( (P_{ij}) \): It is defined as the ratio between power received at the node \( t \)

\[ P_{ij} = \frac{P_{rx}}{P_{tx}} \]  
(IV)

\( P_{rx} \) = power received at the node  
\( P_{tx} \) = power transmitted by the neighbor node.

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

\[ E_{TX} = \frac{1}{(Pkt_{tx} \times Pkt_{rx})} \]  
(V)

Where \( Pkt_{tx} \) = successful packet delivery probability in the forward direction. \( Pkt_{rx} \) = successful acknowledgment packet reception probability.

Distance \( D_{ij} \) : The distance among the two nodes is computed using the free space propagation model.
5.3 Estimation of End to End delay

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

\[ D_{E-E} = (T_{Drx} \cdot T_{Dtx}) \]  

Where \( T_{Drx} \) = data reception time \( T_{Dtx} \) = data transmission time.

5.4 Estimation of Packet loss ratio (PLR)

It is defined as the number of data packets dropped during transmitted to the destination. It is expressed in terms of dropped packets.

6 Proposed technique

In our proposed protocol to select a route bandwidth, battery power, distance, expected transmission time and route quality are taken as parameters. Source node collects all the information from all the destination nodes. These parameters applied to fuzzy inference system to select an optimal route to all the destinations. In this protocol multicasting technique used, so the number of receivers were increased. The algorithm and fuzzy rules are explained in following sections.

6.1 Algorithm for optimal path selection

Step1. When node wishes to send message to group of nodes, it checks the availability of route, if available then goto step 8

Step2. If not broadcast the route request message through intermediate nodes.

Step3. If an intermediate node is having the route to destination transmit to a source, otherwise rebroadcasts the route request to its neighbors.

Step4. Intermediate nodes establish the reverse route in their route tables.
Step4. The node receive RREQ may reply, and it record sequence number for the node.

Step5. The node is receiving RREP from destination updates the route cache about the source address, destination address, previous hop node, battery power, link quality and available bandwidth.

Step6. Source node computes route stability and available bandwidth based on the collected information from RREP.

Step7. The values computed by the source in step 8 are considered as inputs for the fuzzy logic system. Based on the result, Source selects an optimal route that has high route stability and bandwidth value.

Step8. Transmit data to the destination.

6.2 Fuzzy logic system

These processes fuzzify the input variables such as route stability and residual bandwidth. The crisp inputs route stability and residual bandwidth 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 Stability and Bandwidth. Bandwidth (residual), and Path stability are given as inputs, and the output represents the optimal path (OP) for data transmission. The following table given the combination of stability and bandwidth.
6.3 Fuzzy decision-making system

The route stability and available bandwidth combination defines the following rules that are used in the fuzzy logic system and gives the optimal route.

rules[0] = Low Bandwidth and low Stability then the optimal path is very low
rules[1] = Low Bandwidth and medium Stability then the optimal path is low
rules[2] = Low Bandwidth and high Stability then the optimal path is low
rules[3] = medium Bandwidth and low Stability then the optimal path is medium
rules[4] = medium Bandwidth and medium Stability then the optimal path is medium
rules[5] = medium Bandwidth and high Stability then the optimal path is high
rules[6] = high Bandwidth and low Stability then the optimal path is low
rules[7] = high Bandwidth and medium Stability then the optimal
path is high
rules[8] = high Bandwidth and high Stability then the optimal path is very high

This above rule illustrates the function of the fuzzy logic system. The following figures illustrates the membership function of the input and output variables. This utilizes the triangle function widely used in real-time application.
6.4 Defuzzification

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

\[
Fuzzy \ cost = \left[ \sum_{\text{all rules}} Z_i \cdot \lambda(Z_i) / \sum_{\text{all rules}} \lambda(z_i) \right] \quad (\text{VII})
\]

Here fuzzy cost is used to specify the degree of decision making. \( z_i \) is the fuzzy all rules, and variable and \( (z_i) \) 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.

7 Simulation results

This section outlines the result of unicast and multicast routing protocols NS2. Network simulation deployed in an area of 1000X1000 m. The destination is assumed to be situated 100 m away. The channel capacity is 2 Mbps, and simulated traffic is CBR with UDP source and sink.
The performance of CBRM protocol is compared with the PDTMRP. The simulation is evaluated according to the following metrics.

- Packet Delivery Ratio: It is the ratio of the number of packets received successfully by destination node and the total number of packets transmitted by the source node.
- Drop: It is the number of packets dropped during the transmission.
- Delay: It refers to the average end to end delay of packets.

8 Results

8.1 Based on Receivers

When the number of receivers changed to 2, 4, 6, 8 in this simulation and number of nodes and pause time were constant time delay increased rapidly in PDTMRP protocol and slowly increased in CBRM. The delivery ratio is maximum when a number of receiver nodes are minimum, but the delivery ratio is minimum when the number of nodes increased in both protocol. The time delay is minimum in CBRM than PDTMRP.[Fig 2,3,4].
8.2 Based on Nodes

When a number of nodes increased packet drop is increased but suddenly decreased at 125 in both protocols but packet drop increased when nodes increased to 150. However, packet drop is minimum than the PDTMRP [Fig]. The delay increased slowly from nodes 50 to 100 but decreased at 125 nodes; PDTMRP delay is maximum than CBRRM [Fig]. In Nodes Vs Delivery ratio it indicates delivery ratio is continuously decreased when the number of nodes increased. At the same time delivery ratio decreased when a number of nodes 125 then it increased but CBRRM delivery ratio is maximum than PDTMRP [Fig 5, 6, 7].
8.3 Based on pause time
9 Conclusions

In this paper, we have implemented the cross-layer based multicast routing protocol with fuzzy logic. This protocol collects the values route stability and bandwidth from various nodes in multiple routes. Then fuzzy logic system applies fuzzification process-Fuzzy decision-making process-Defuzzification process to select the optimal route. This selected route having more stability to data transmission and our proposed protocol increases deliver ratio, decreases delay and reduce the packet drop. As future work, we propose efficient rate control in the multicast routing protocol.

References


