Implementation of AODV protocol with and without fuzzy logic for reliable multicast routing in adhoc networks

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Abstract — A major aspect of adhoc networks is that the nodes can move randomly, which requires the routing protocols in adhoc network to quickly respond to the network topology change in order to guarantee successful data packet delivery. Multiple routing paths are established to provide extra schemes of video streaming or multicast transmission and enhance the robust transmission against unreliability and limited bandwidth of wireless links. In this paper, AODV routing protocol can be modified with fuzzy logic named fuzzy modified AODV routing (FMAR) protocol for multicast routing in mobile adhoc networks . The fuzzy logic weighted multi-criteria of the protocol is used to dynamically evaluate the active route life time in order to determine the appropriate routes. Due to frequent node movements, the topologies of mobile adhoc networks change rapidly . The Fuzzy rule base depends upon the number of hop counts, sent controlled packets and the energies of the nodes on the routes. The enhancement of FMAR protocol was implemented for quickly maintain and repair the routes with the dynamic Lifetime of the routing table before they crashed. The Fuzzy rule base depends upon the number of hop counts, sent controlled packets and the energies of the nodes on the routes. The simulation results of enhancement of FMAR protocol will be efficient than FMAR protocol with respects to the node mobility, the packet delivery ratio, average route acquisition latency delay, the routing overhead and the average end to end delay.

IndexTerms —— AODV Protocol , FMAR protocol, Fuzzy logic, Multicast routing, Network lifetime, Network simulator

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1 INTRODUCTION

An adhoc network is a collection of mobile nodes. Usually it has no centralized or fixed infra structure. Therefore its topology changes frequently. The main characteristics of adhoc networks are node mobility and node power control practices. The routing paths that consist of a number of wireless links are frequently blocked and then reestablished during time period of packet transmission. Hence the quality of wireless links often fluctuates due to the channel fading and the interference from other communications. Owing to the unexpected congestion or block of routes and the limited bandwidths of wireless links, it is hard to guarantee the packet delivery and it is also hard to provide good qualities of multicast. To overcome this defect, establishing multiple paths between a sender and receivers. AODV is an on-demand distance vector routing protocol. The protocol is well known for the use in adhoc networks. Our protocol in this paper is a fuzzy modified aodv for multicasting.

In aodv, the lifetime field of the routing table entry is static, which is either determined from the control packets or initialized to route lifetime (LT)[9]. AODV has a table-driven routing framework and a set of destination sequence numbers. It relies to a certain extent on timer-base activities

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(routing table entries expiration timers). If a route is not used recently, the entry is expired. AODV has a mechanism to expired stale route or prefer "fresher" route when it faces with multiple choices[8]. For route discovery, the source broadcast a RREQ to find route to destination, the receivers follow the reverse paths pointing towards the source. The destination replies RREP back to the source; the reply packets including some information are generated by intermediated node following the precursor list. For route maintenance, an existing routing entry may be invalidated to the destination node. In that case, the invalidation is propagated to their next hop node. For route repair, when an intermediate node moves, its upstream neighbors will propagate RERR message to each of its active upstream neighbours.

Concerning the multicast, various protocols have been proposed for adhoc networks[3].They can be classified in to two types according to their configurations. One of the two types is tree-based (e.g., Adhoc multicast routing (AMRoute) ,and Adhoc Multicast routing protocol utilizing increasing id-numbers (AMRIS) [10] and the other is mesh-based (e.g., on-demand Multicast routing protocol (ODMRP) and core-assisted mesh protocol(CAMP). There are many investigations in the area of multipathsR. transmission (MPT)[16][2].Although the selection of an optimal path set is an NP-complete problem. The split multipath routing (SMR) protocol [2] as an on-demand routing scheme built maximally disjointed multi-paths, which efficiently utilizes the available network resources to simplify the route recovery process and minimizes control

message overhead. The SMR always constructs two maximally disjointed routes from a source to a destination after finishing the routing discovery. In a word, the use of static discovery to determinate multi-paths is hard to cope with instantaneous environmental variation in an adhoc network. Due to the complexity of the determinate variable route life time of the multipaths, only a few network researchers attempted to dynamically evaluating the route lifetime parameters in order to determinate route selection, maintain and repair.

Referring to the route lifetime, the route life time is equal to zero when the route is active during transmission, and it should be deleted at the end of the transmission, and that the route lifetime is equal to infinity when the route is inactive. In AODV, route lifetime (LT) is equal to a predetermined static value and in milliseconds. Route life time is the period of time that the route can stay active in the routing table. It is restricted and equal to an adaptive value[15] proposed that the path between two nodes should be remained in the routing tables along as the minimum parameter (route lifetime) is greater than a certain threshold. They stated that the route life time is an un-restricted adaptive lifetime, introduced the adaptive route lifetime method to minimize routing delay and overhead. They used mathematical tools to determine the values of adaptive route lifetime. The node movement and node power consumption are difficult to be predicted, the dynamical evaluation of the route lifetime is better than that statically assigned by AODV. The protocol applied a fuzzy logic system to dynamically evaluate the route expiry time. The fuzzy logic is chosen because there are uncertainties associated with node mobility and the estimation of link crash, moreover, there is a mathematical model can be capable of estimating the node mobility. In addition, this fuzzy multicast routing protocol is satisfactory to take some controlling factors (such as the node remained energy) in to consideration. Therefore, our protocol is a multi-criteria fuzzy evaluation for multicast routing protocol. In this paper, the packets are multicast via multiple paths to multiple receivers of a multicast group instead of successively performing single cast in adhoc networks. The technique determinates the two most stable routes from a source to a destination. One of the routes acts as the main path and the other path for extra function route. Thus, when the main path is unreliable, it can be replaced immediately by the preferred alternative. For constructing our multicast routing protocol, modify the approach of AODV to establish the two most stable paths [3].

The Fuzzy Logic Weighted Multi Criteria determines the appropriate routes to a multicast group. The constructed protocol is called FMAR (fuzzy modified AODV multiple routing). The advantages of FMAR are that a source can apply the multiple routes to successfully communicate with its receivers and that each multicast

route has mesh topology to deal with the suddenly crashed links during transmission. The FMAR make route decisions according to the replied messages containing the information of remained energies of the nodes on the routes, the number of hop-counts and the sending control packet of the intermediate node on the route. The FMAR applies a set of definitions (membership functions) and a set of rules (rule-bases) to select a most appropriate main route and an alternative route and let them stay active in the routing table. The route maintenance and repair will be handle in accordance with route life time information to keep multicast smooth going in adhoc network, so that the packet delivery may be reliable.

2 MULTICAST ROUTING PROTOCOL WITH MULTI-PATHS

In adhoc networks, the goal of establishing multiple routing paths is to solve the problem of the sudden breaks of routing paths from a source to receivers. The fuzzy modified AODV multiple routing (FMAR) is designed for the above purpose. The design procedure is as follows: Fig. 1illustrates how the source S1 establishes a multicast group including two receivers (R1, R2). The forwarding nodes forward the requests and relay the reply. In the request phase, a source node (e.g. S1) floods a RREQ packet as an advertising packet throughout the entire network. The next nodes receive a non-duplicated RREQ and record the upstream node address (S1) in its routing table, and then reflood the RREQ. Finally, after accepting the RREQ, the multicast receivers reply RREPs to the sourceS1. The receiver waits for a suitable amount of time so that all possible routes can be gained. In the reply phase, a receiver traces back by increasing Hop Counts along the reverse paths to the source to record the energy and the number of control packets of intermediate nodes. By the use of fuzzy logic weighted multi-criteria, the source selects the most stable route with maximum route lifetime instead of selecting the minimum delay time route. The remaining routes are stored in the routing table to be used as the second routes to establish the most stable route if it crashes.
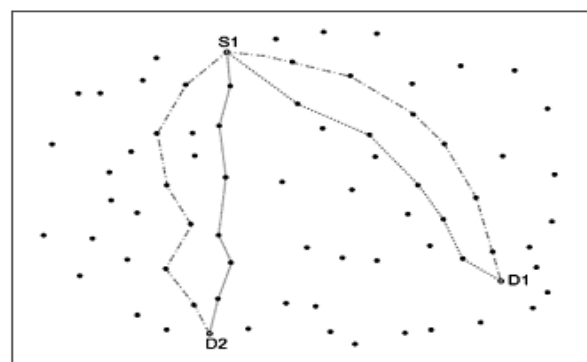

Fig. 1. The source S1 select two comparatively stable disjoint routes for destination D1 and D2, respectively.

3 FUZZY RULE BASE AND METHOD FOR DETERMINING ROUTES

In this section, we modify AODV and introduce the fuzzy logic weighted multi-criteria for assigning active route lifetime (LT) of each entry in the routing table. For the purpose of reducing the precious bandwidth and the overhead of transmission via void, the routes are determinate dynamically. Therein, a reliable route should be a route with maximum expiry time and should be substituted when it is unavailable. A source node in the ad hoc network has multi-paths to each destination. If the route is not used for a period of time or the lifetime is small, the route entry has high probability to expire due to high probability of its instability. The route will be partially repaired when the lifetime of the route is going to be less than a certain threshold. This approach is useful for computing route lifetime by the different criteria under the fuzzy environment. The practical problems are often characterized by several non- commensurable and competing (conflicting) criteria. The considered criteria can be based on the evaluation of the route characteristics including HopCount, the number of control packets and the lowest energy of the route node. Having defined the fuzzy linguistic rules, the HopCount is an evaluation criterion for Lifetime (active remain time in the routing table) and is described as the number rating of nodes along the route between the source and destination. When the HopCount is high, the probability of route broken is also high because of node's mobility. Therefore, the time that the path remains in routing table (the lifetime) should be smaller, thus the rating of Lifetime (expressed by LT) will be given small similarly. Consequently, the rules should be as follows: membership functions corresponding to each element in the linguistic set (HopCount, SntCtrlPkt, EngyMin and Lifetime) must be defined. We present the method to design its membership functions. The criteria rating can be assessed by linguistic terms (dimensionless index) such as very low (VL), low (L), medium (M), high (H) and very high (VH). The linguistic rating scale applied is illustrated in Fig. 2, and the membership functions of the five linguistic values are shown in Fig. 3.

H1: If Hop Count is very high, then LT is very low.
H2: If Hop Count is high, then LT is low.
H3: If Hop Count is medium, then LT is medium.
H4: If Hop Count is low, then LT is high.
H5: If Hop Count is very low, then LT is very high.

The membership functions for Hop Count and LT rating value are expressed with dimensionless index within [0, 1] as shown in Fig. 2. In general, the LT is an inverse ratio to Hop Count. SntCtrlPkt is sum of the number of sent packets and the number of received packets. It is also a valid factor to evaluate the LT of the route entry in the routing table.
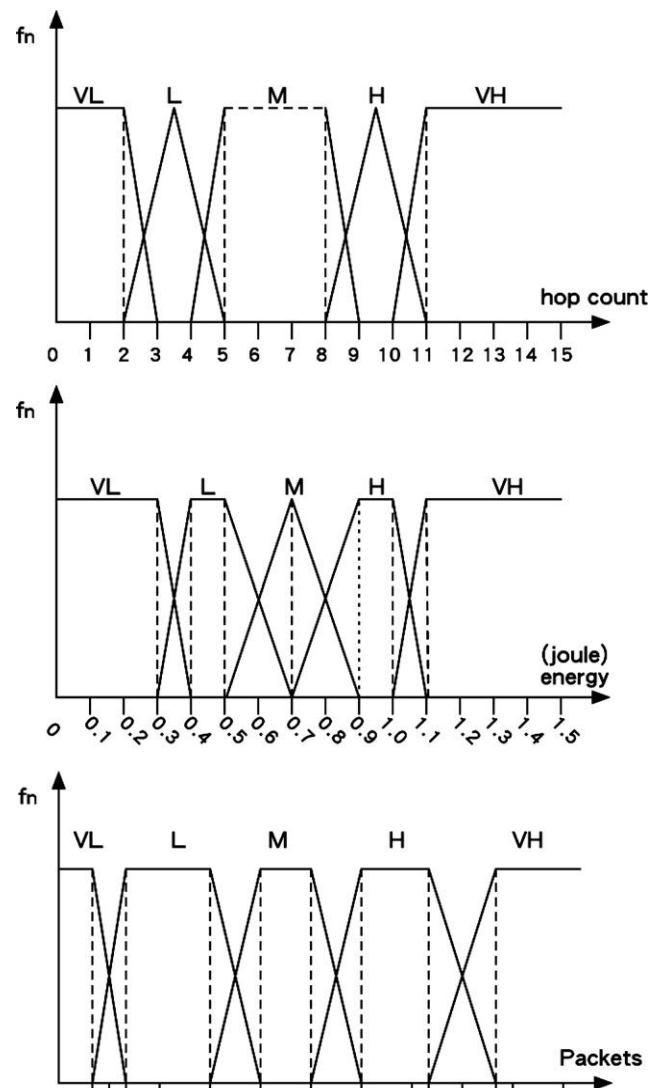

Fig 2. Rating scale for accessing hop count, sentctrlpkt and energymin criteria (VL,verylow;L , low; M , medium;H high;Vh-very high)
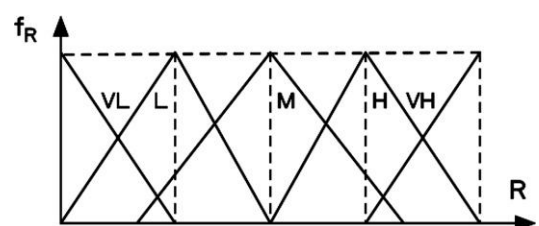

Fig. 3. Membership functions for linguistic rating values (VL, very low (0, 0, 0, 0.3); L, low (0,0.3,0.3,0.5); M, medium (0.2, 0.5, 0.5, 0.8); H, high (0.5, 0.7, 0.7, 1); VH, very high (0.7, 1, 1, 1))

If the transmission is interrupted or the nodes move frequently, then the link would very probably break, and

then the control packets would increase. When the route is congested, the shared bandwidth of channels would be reduced, so that the route became unstable due to the retransmission of the lost packets. The control packets can be any one of the following types: HELLO, RREQ, RREP, RERR and RREP_ACK. If the RREP packet records the number of sending control packet of the intermediate nodes is high, it represents the route is probably unstable. So, high number of these packets means high probability to lose some of its current links or packets.

The rules for the relationship between SntCtrlPkt and LT are:

 N1: If SntCtrlPkt is very high, then LT is very low.
 N2: If SntCtrlPkt is high, then LT is low.
 N3: If SntCtrlPkt is medium, then LT is medium.
 N4: If SntCtrlPkt is low, then LT is high.
 N5: If SntCtrlPkt is very low then LT is very high

Similarly, The SntCtrlPkt rating value is expressed with dimensionless index within [0, 1] and the LT is an inverse ratio to SntCtrlPkt. In addition, the energy characteristic can also be considered as an evaluation criterion. We use the energy consumption rate as the parameter to describe the power condition of an arbitrary node i. We denote the power consumption rate as PC_i. The value of PC_i is evaluated with a very simple method that is similar to that in[2]. Since the power consumption of a node is caused by the transmission, reception, and overhearing of packet activities, we define PC_i by the equation as below:

$$PC_i = \frac{(W_r \times M_r + W_s \times M_s + W_o \times M_o)}{T}$$

$$RT_i = \frac{RP_i}{PC_i}$$

Where PC_i =Power consumption rate.
  W_r =Power consumed by the network interface when node i receives a packet
  W_s =Power consumed by the network interface   when node i sends a packet.
  W_o=Power consumed by the network interface when node i overhears a packet.
  T = Time period during the node i consumes its energy.
  M_r, M_s, M_o are the amount of received, sent and overhears packets.
  RP_i= Remaining battery energy of the node i.
  RT_i = Residual time of the node i.

The life time of the route is related to, Min RT_i = Energy min.

If the EngyMin is low, the probability of the link broken will be high. Thus, the rules for the relationship between EngyMin should be as follows:

 E1: If EngyMin is very high, then LT is very high
 E2: If EngyMin is high, then LT is high
 E3: If EngyMin is medium, then LT is medium
 E4: If EngyMin is low, then LT is low
 E5: If EngyMin is very low, then LT is very low
    Contrarily to the relationships between Hop Count

and LT and between SntCtrlPkt and LT, the LT is a direct ratio to the EngyMin. Considering the former two criteria, the membership function for EngyMin criterion should be considered as the dimensionless index [0, 1]. Based on this concept, the reverse energy limit, RvEngyMin, is defined as RvEngyMin = (1-EngyMin).

The membership functions for the rating values of EngyMin and RvEngyMin are respectively expressed by the two equations as below:
The value of EngyMin = (a, b, c, d) and
The value of Rv EngyMin = (1-d, 1-c, 1-b, 1-a).

This rule-base is to be employed to build the fuzzy system as described below:
The LT ratings of the different routes to the same destination under weighted multiple criteria are evaluated. The membership function of rating values is assigned as F(i) for the route i. Here, we respectively correspond the membership function H(i), S(i), E(i) and RvE(i) to Hop Count, Sent-CtrlPkt, EngyMin and RvEngyMin. The membership functions E(i) and RvE(i) of the EngyMin rating value are expressed as follows:
E(i)=(a,b,c,d) and RvE(i)=(1-d,1-c,1-b,1-a)

The above rules can be combined with a rule base as represented in below table:

Table 1

The ratings of the alternative routes according to the three criteria described above

	HopCount	SentCtrlPkt	EngyMin
R1	VH	H	L
R2	M	VL	M
R3	H	L	VH
R4	L	M	H
R5	VL	VH	L

The final rating is the fuzzy suitability index for   each candidate route i which can be calculated by the following equation:
  F (i) =H(i) * Wh +S(i)* Ws +RvE(i) *We
       Where Wh+Ws+We =1.
  where Wh, Ws and We is the weighting factors for H(i), S(i)and RvE(i), respectively. These factors respectively depend on how the route is influenced by H(i), S(i) and RvE(i). F(i) is the approximated fuzzy number corresponding to the fuzzy index of the alternative route i. Further, we can list the final rating of the various routes to obtain the suitability index of the alternative route i.

4 PERFORMANCE METRICS
4.1 Packet delivery ratio:

It is defined as the ratio of the number of data packets received to the number of data packets sent between the source and the receivers.

4.2 Average end to end delay:
It is the average delay between the sending of the data packet by CBR and its receipt at CBR receiver.

4.3 Average route acquisition latency delay:
The average delay between the sending of a RREQ packet by a source for discovering a route to destination and the receipt of the first corresponding RREP packet.

4.4 Routing overhead:
It is defined as the ratio of the total number of control packets sent to the number of data packets delivered successfully.

5 SIMULATION ANALYSIS
The benefits of fuzzy modified AODV (FMAR) routing protocol can be demonstrated by the performances of the protocol with respect to packet delivery ratio, end-to-end delay, average route acquisition latency delay and routing overhead are simulated using the NS2. The FMAR functions and the lifetime of the routing agent are coded using C++ Toolkit to determine the membership functions. The mobility model used in each of the simulations is in a random direction mode. In each ad hoc network group, the nodes are initially placed randomly within a predefined 500 m * 500 m grid area. Each node then chooses a random direction between 0 and 360 degrees and may move at a speed within 0–20 m/ s. Once a node reaches the boundary of the area, it chooses a time period for remaining stationary. After the end of this pause time, the node chooses a new direction between 0 and 180. The new direction is adjusted according to the relative position toward the boundary of the area. This process is repeated throughout the simulation, and then the topology of the underlying network changes continuously. We used some applications of FTP and HTTP and a few generic CBR source with 1000 bps for generating the traffic. We simulated several rounds to change the couples of senders and receivers using topology and traffic generators. The simulation time for a round is 1500 s at the most.

5.1 Packet delivery ratio vs node moving speed
Fig. 4 shows the performance analysis of the achieved packet delivery ratio vs. node moving speed for the FMAR, AODV and the enhancement of FMAR protocol in an ad hoc network. packet delivery ratio is similar to throughput in that it represents the ratio of the number of data packets received to the number of data packets sent between the source and the destinations. Using AODV as a base line for comparison, the result shows that both FMAR and the enhancement of FMAR are much better than AODV protocol. This is because that AODV needs to

rediscover the route to retransmit data packets that are lost due to the node's mobility or unreal route paths during the communication
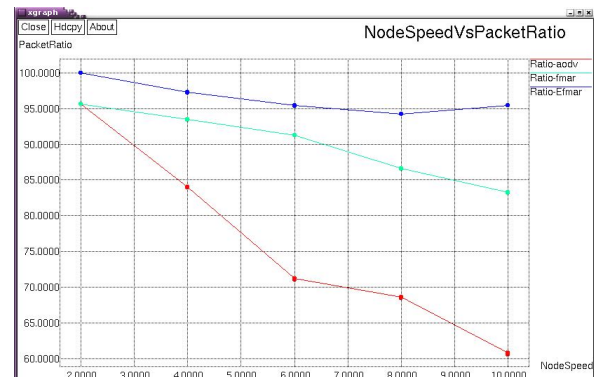

Fig 4 Node speed vs packet delivery ratio

5.2 Average end to end delay vs node moving speed
Fig. 5 shows the comparison of the three protocols with respect to the average end-to-end delay vs. node moving speed. It shows that the end-to-end delay increases usually with the increasing speed. It also shows that the enhancement of FMAR protocol is much better than the other two, and that the change of the delay in enhancement of FMAR is smoother than those in the other two. AODV needs more time and more control overhead than the FMAR does to recover unreal paths (broken paths) and to discover new paths.
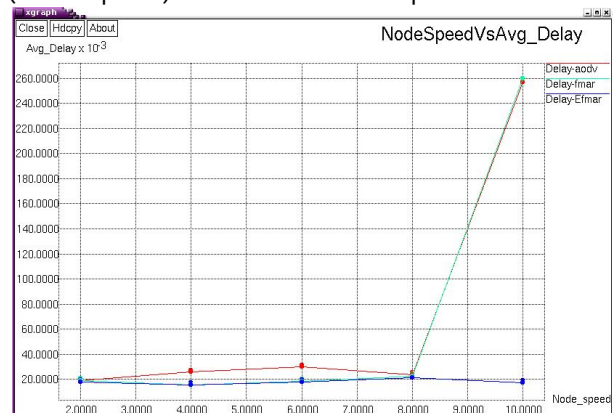

Fig 5 Average end to end delay vs node moving speed

5.3 Average route acquisition latency delay vs. simulation time
To show that the enhancement of FMAR can find the appropriate routes in time before crashing, the average route acquisition latency delay vs. simulation time is examined. The delay is computed by noting the simulation time during the period from the time an initial RREQ or the RREQ for the re-established route are broadcast to a given destinations to the time the RREPs are received by the source. Fig. 6 shows average route acquisition latency delay vs. the simulation time. It indicates that the enhancement of FMAR protocol is also much better than

the other two with respect to the performance of the average route acquisition latency delay.
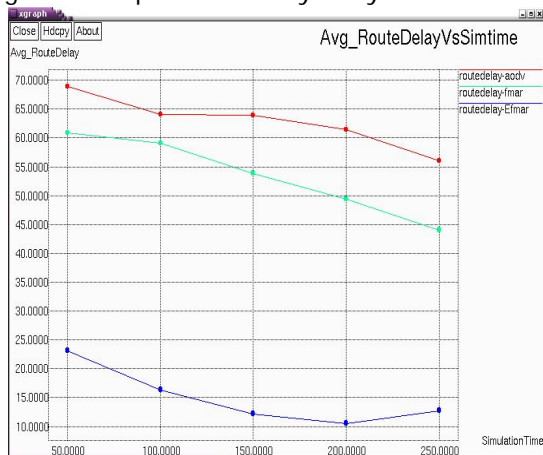

Fig 6 Average route acquisition latency delay vs simulation time

5.4. Routing overhead improvement ratio vs. simulation time

Fig. 7 shows the routing overhead improvement ratio vs. simulation time. Both the ratios are respectively obtained by dividing the overheads of FMAR and AODV based on the overhead in terms of RREQ, RREP and RERR messages sent. Since FMAR selects two comparatively stable disjoint routes for transmission instead of the quick one as AODV, therefore, the duration of routes in FMAR is better than that in AODV. When the Simulation time increase, the AODV is highly probable to use the re-established more stable routes therefore, the AODV is closer to FMAR. The enhancement of FMAR protocol is much better than the FMAR and AODV.
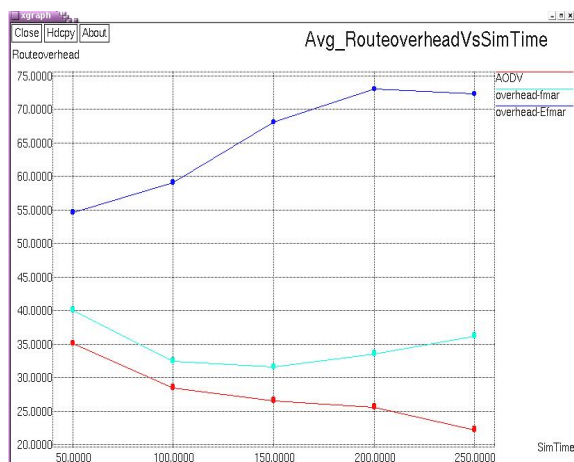

Fig 7. Routing overhead improvement ratio vs. simulation time

6 CONCLUSION

In this paper, fuzzy modified AODV (FMAR) multicast routing protocol is proposed to select two comparably stable routes by computing dynamic route lifetime for multicast routing or layered video streaming.
The model compares and ranks different route lifetimes by the weighted Multi-criteria. The simulations of the performances of the packet delivery ratio, the average end-to-end delay, average route acquisition latency delay and routing overhead are carried out for FMAR, AODV and the enhancement of FMAR protocol. The results show that all the performances of the former two are much better than that of AODV, and the enhancement of FMAR protocol is significantly better than FMAR protocol with respect to the performances mentioned above.

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