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FLMR: Fuzzy Logic Multipath Routing Algorithm in[1] Mobile Ad Hoc Networks

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Wireless mobile ad hoc networks are infrastructure networks that nodes move repeatedly and it causes to change topology. So routing is important for mobile networks.when a route is destroyed, the path discovery must be done. This operation leads to consume more energy and increase end to end delay. In the present paper, a new algorithm is proposed in which multiple path are funded using fuzzy logic. Priority is a defining factor to select a path. Increasing packet delivery and decreasing end to end delay are result of proposed algorithm.

Keywords: *Mobile Ad hoc Networks, Fuzzy Logic, Multipath Routing, Membership Function.*

1. Introduction

Routing in mobile ad hoc networks is very important for its dynamic topology more. Ever there exist some nodes whose energy sources are limited in computation and communication. Routing protocols are divided into two categories: 1) single path 2) multiple path.

Some protocols use single path for sending data while others use multiple path. When active path or all of discovered paths toward destination are destroyed, process of path discovery is done. This process is finished while enough paths or all of possible paths into destination are discovered [1]. [2] In the present study, AODV routing algorithm, the proposed algorithm (FLMR) simulations and results would be presented.

2. AODV[2] Algorithm

AODBV is a modified version of DSDV[3] protocol [6]. to finds a path toward destination, source node broadcasts path request packet through adjacent nodes. Request packet would be discovered by any node visiting twice. Request packet use sequence numbers to avoid creating ring. Just while the intermediate nodes receive new information from path they reply into request packet [3]. Each node would be save the first node sending data in routing table to use inverse path for replying. When reply packet is sent to source, middle nodes of selected path set their routing table based on it. If a connection is broken, error message is forwarded to source node for reconstructing path [4] [5].

3. Proposed Algorithm (FLMR[4]): In general, routing has two parts: path discovery and path maintenance.

3.1. Path discovery. Structure of routing at FLMR includes 3 sections: finding multiple paths with modifying at AODV, collecting local connection and total path, calculating suitable path for requirements of application by fuzzy controller.

3.1.1. Finding multiple paths. Discovery path at AODV can find multiple paths. Often data would be sent via optimum path in AODV and several paths are used by maintenance phase while in FLMR some paths would be used in both maintenance and discovery path phase. At this algorithm, when several paths are constructed, sending data would be started.

[1] Печатается в авторском варианте
[2] Ad-hoc On Demand Distance Vector
[3] Destination Sequenced Distance Vector

[4] Fuzzy Logic Multipath Routing

3.1.2. Collecting Status Connection. This algorithm search the suitable path and local status is updated for all output connecting based on it. Information of connection includes delay of radio dispersion, queue, and protocol process, in addition reminded bandwidth and cost (c, j).

In each node, either MAC layer protocol obtains local status by adding some operations on recent MAC layer such as 802.11, MACAW or adjusting system of MAC protocol. In the present paper, it is assumed that 802.11 is used for collecting local delay between anode and its neighbours. Bandwidth is calculated by adding operation of reserved source. All local connection status is saved in local status table. Used parameters in this algorithm are described as following:
Path = *a*->*b*->...*f*->g that above parameters must be obtained for it.
Path delay (*D*) = delay of (*a*, *b*) + ... + delay of (*f*, *g*).
Path bandwidth (*B*) = min{bandwidth of (*a*, *b*) + ... + bandwidth of (*f*, *g*)}.
Cost of path (*C*) = cost of (*a*, *b*) + ... + cost of (*f*, *g*).

To collect status paths, 3 fields are inserted to RREP form of AODV message. Destination node replaces the local status in RREP when sending for first time. Then intermediate nodes fill the field according RREP information and its status. Finally source node can obtain multiple paths with different priorities.

3.1.3. Select Fuzzy Path. In last case (9), suitable paths for an applicant request would be determined. Fuzzy logic would solve ambiguous problems in networks. Figure 1 shows proposed fuzzy controller including *3* fuzzy controller and a path selection model. Fuzzy member functions are triangle (*x*, *a*, *m*, *b*) and (*x*, *a*, *m*, *n*, *b*). [7]

$$Tri(a,m,b)\begin{cases}0, x \le a \\ \dfrac{x-a}{m-a}, x \in (a,m] \\ 0, a = m \\ 0, b = m \\ 0, x \ge b \\ \dfrac{b-x}{b-m}, x \in [m,b) \end{cases}$$

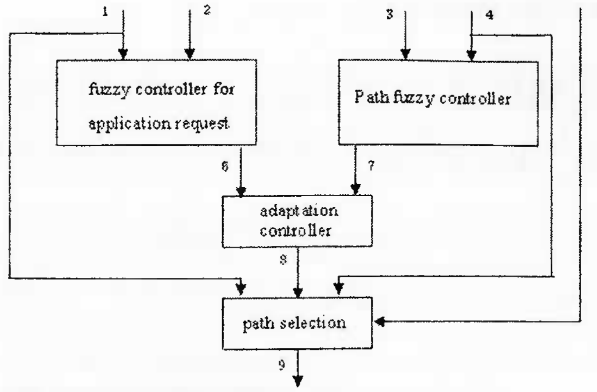

Figure 1: Structure of fuzzy controller in FLMR algorithm:
1 — request bandwidth; *2* — request delay; *3* — path bandwidth; *4* — path delay; *5* — cost of path; *6* — result of fuzzy request; *7* — fuzzy path status; *8* — degree of fuzzy adaptation; *9* — selected paths

$$Trap(a, m, n, b)\begin{cases}0, x \le a \\ \dfrac{x-a}{m-a}, x \in (a,m] \\ 1, x \in [m,n] \\ 1, b = n \\ 0, x \ge b \\ \dfrac{b-x}{b-n}, x \in (n,b) \end{cases}$$

A. Fuzzy controller for application request

Bandwidth request and end-to-end delay are input variables and result of fuzzy request according language rules is the output. Bandwidth of MANET is 0.2 m b/s. Bandwidth request is divided into *5* classes: {*R*1, *R*2, *R*3, *R*4, *R*5} is presented in table *1* as.

Figure 4 shows the graphic display of member functions for request bandwidth. For real time applications such as voice and video, average end-to-end delay restrict to 5 ms and 25 ms respectively. So end to end delay language variables are shown by as figure 2. Figure 5 shows graphic display of member function for end-to-end delay. Fuzzy rules

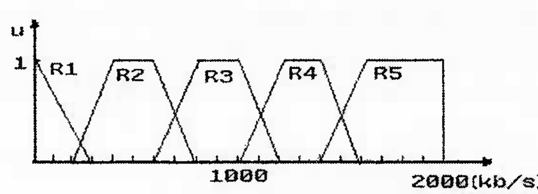

Figure 2: Membership function for request bandwidth

can be selected from experts, experiences or other total rules. considering the fact that application of fuzzy sets in MANET are not well understood using experiment rules is difficult. So we use developed fuzzy theory for estimating rules.

Definition:

Following factors are set for fuzzy decision.

F = {(RB) request bandwidth, (D) end-to-end delay}

Evaluation set:

C = {Higher ($c1$), High ($c2$), Medium ($c3$), Low ($c4$), Lower ($c5$)}

If fi (i = 1,2) equal with ci, fuzzy decision matrix R ($C1$, $C2$) can be constructed and fuzzy set A = = ($A1$, $A2$) would be used to show the effect of each parameters at evaluation. $A1$, $A2$ define value of request bandwidth and end-to-end delay respectively. If we use triangle rule operators then results of evaluation are as following:

$B = A \cdot R$ in which $bj = \sum(a_i \cdot r_{ij})(j = 1, ..., m)$

The maximum value of requested bandwidth and end-to-end delay would be returned according to general rules of membership degree. For instant while request bandwidth is $R1$ and end to end delay is s then:

$$R = \begin{bmatrix} 0 & 0 & 0 & 0.2 & 0.8 \\ 0.9 & 0.1 & 0 & 0 & 0 \end{bmatrix};$$

$$A = 0{,}4;\ 0{,}6;$$

$$И = 0{,}54;\ 0{,}06;\ 0{,}008;\ 0{,}032.$$

In the meantime fuzzy decisions of requirements set {$R1$, S} are maximum. The rules are summarized at table 3.

1. Fuzzy set for request bandwidth

Parameters	Function type	Fuzzy set
$R1$	TRI	[0, 0, 300]
$R2$	TRAP	[200, 400, 600, 800]
$R3$	TRAP	[600, 800, 1000, 1200]
$R4$	TRAP	[1000, 1200, 1400, 1600]
$R5$	TRAP	[1400, 1600, 1800, 2000]

Table 2: Fuzzy set for end to end delay

Parameters	Function type	Fuzzy set
S	TRI	[0, 0, 10]
M	TRAP	[0, 12, 25, 50]
L	TRAP	[25, 50, 100, 100]

Table 3: Linguistics rules for fuzzy controller (RB: Request bandwidth, D: End to End Delay)

RB/D	$R1$	$R2$	$R3$	$R4$	$R5$
S	Higher	Higher	Higher	Higher	Higher
M	Medium	Medium	Medium	Medium	Medium
L	Lower	Low	Medium	High	Higher

B. Fuzzy path controller

Conducts fuzzy processing for path discovery and its structure is like traffic fuzzy controller but different in input and output variables. Path delay and path bandwidth are input variables.

C. Adaptation controller

Control rules for this element are based on adaptation degree between result of fuzzy request and path status.

$$MD = \begin{cases} 1, \text{Fuzzy Route State} \\ 0, \textit{other} \end{cases}.$$

If MD = 1, selected path is valid otherwise path is invalid.

D. Path selection

If path bandwidth is equal or more than request bandwidth, program go to step 2 else go to step 4. among different paths meeting first condition would be selected with minimum cost then program go to step 3. Reserved bandwidth program start on each connections of selected path for reserved requirements. When the user session finishes,reserved bandwidth will become free.

3.2. Path Maintenance. When several paths are destroyed, source node receive error information from REPR message and it changes corresponding input at cache.this mechanism is still like that of AODV.while existing another path toward destination at cache, it will be dedicated to another session to provide its requirements.

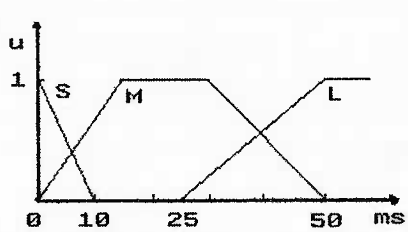

Figure 3: Membership function for end to end delay

4. Simulation

Glomosim provides a simulation area for wire line and wireless communication networks. it simulates networks with maximum 1000 nodes connecting each other heterogeneous. Figure 1 to 3 represent simulation results of AODV and proposed algorithm. Area of simulation for proposed algorithm is 1000·1000 m with transfer radios 100 m for each node. Rate of sending data packet is 10 packet at a second with size of 512 byte. Duration time of simulation is 30 second. At this section we compare FLMR algorithm with multiple path and AODV with single path. From different points of view including rate of packet delivery, end-to-end delay and rate of packet lost. Figure 1 shows increasing rate of packet delivery at proposed algorithm relative to AODV algorithm. Figure 2 illustrates that rate of packet lost decreased in proposed algorithm comparing with that of AODV. at last, figure 3 shows that average end-to-end delay has been modified against AODV algorithm.

5. Conclusion

In the present paper, AODV algorithm is modified in which multiple paths are used instead of single path. Using fuzzy logic, the paths are categorized based on their priorities. If a using path fail then path with second priority is selected. Proposed algorithm was compared with AODV and results shown that packet delivery increased, packet lost and end to end delay decreased compare with AODV.

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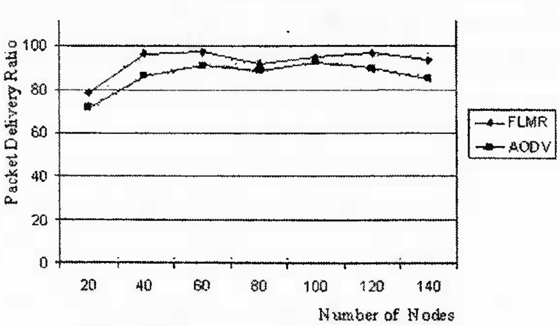

Figure 4: Packet Delivery Ratio in tow FLMR and AODV Algorithms

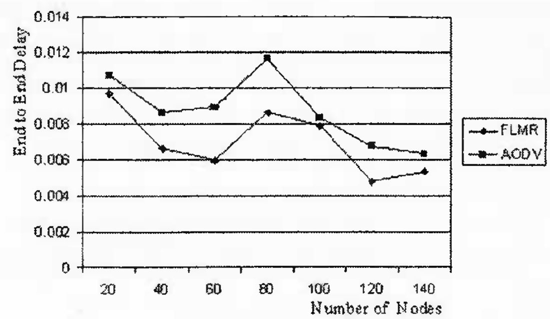

Figure 5: End to End Delay in tow FLMR and AODV Algorithms

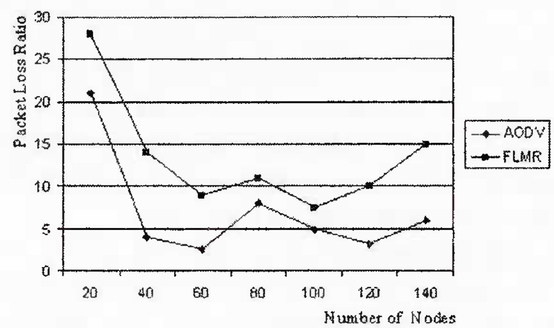

Figure 6: Packet Loss Ratio in tow FLMR and AODV Algorithms

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