Fuzzy Cost Based Multi Path Routing For Mobile Ad-hoc Networks

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***Abstract*--** **In this paper we describe an idea of selecting best paths from multi path [1] routing from source to destination node in Mobile Ad-hoc Networks (MANETs) using fuzzy cost. This is based on multi criterion objective fuzzy measure. We have made changes to Improved Rank-based Multipath Routing (ImRMR) in Mobile Ad-hoc Networks [10]. In ImRMR, Generally paths are categorized using rank fitness. But in our proposed method paths will be categorized using a new idea of fuzzy cost fitness, which tends to minimize the disadvantages of both unipath and multipath routing methods. In our method, we transform the attributes values (resources available) of the path (i.e. fuzzy measures or resources available) converted in to fuzzy costs. The path with the cost more than the defined threshold value will be considered to be the effective one and will be used for sending data from source to destination.**

***Index Terms*--** **Multi path, fuzzy cost, fuzzy cost fitness, rank fitness**

I. Introduction

THIS document provides an example of the desired layout for a PES technical work and can be used as a template for Microsoft Word versions 6.0 and later. It contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided that explain how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors' biographies. For additional information including electronic file requirements for text and graphics, please refer to the IEEE Power Engineering Society Author's Kit. The kit may be obtained from the PES web site at http://www.ieee.org/power, or the PES Executive Office, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA, phone: +1 732 562 3883, fax: +1 732 562 3881, pes@ieee.org.

II. Literature Survey

One class of protocols is based on preparation of information tables and where as the other class is with out them.

DSDV protocol [2] has been specifically targeted for mobile networks. It augments the classical, distributed Bellman-Ford [6] algorithm by tagging each distance entry $d_{ik}(j)$ by sequence number that originated in the destination node i. Each node maintains this sequence number, incrementing it each time the node sends an update to the neighbors. For equal sequence numbers the one with the smallest distance metric is used. DSDV avoids both the long-lived loops and count-to-infinity problems.

The above table driven approaches are simple, but cost too much memory to maintain information tables and also consume too much bandwidth inorder to refresh the information periodically, since every mobile need to maintain its own information table.

In another class of on demand algorithms (i.e. no need of preparation of information table), for example, Dynamic Source Routing (DSR) [8], proposed by Broach et al,the routing , path is established only where the Routing Request (RREQ) reaches the mobile device. The Ad-hoc On-Demand Distance Vector (AODV) [4], proposed by Perkins et,al ,finds a more stable routing path with a lower block probability. This method typically selects the shortest route among several possible ones.

In the literature very few routing algorithm will exists for MANET using fuzzy logic these are Fuzzy Logic Wireless Multipath Routing (FLWMR)[15] and Fuzzy Logic Load Aware Multipath Routing (FLWLAR) [15].

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TABLE I
THE RESOURCE ALLOTTED TO FIVE PATHS

Vector	Bandwidth	Comp Efficiency	Power Cons	Traffic Load	No of Inter Nodes
1	60	400	50	0	4
2	40	350	40	3	3
3	30	200	55	2	1
4	20	450	70	1	2
5	70	100	60	4	5

TABLE II
THE COST VALUES FOR ALLOTTED RESOURCES

Vector	Bandwidth	Comp Efficiency	Power Cons	Traffic Load	No of Inter nodes	Total Vector Cost
1	0.85	0.888	0.28	1	0	3.018
2	0.571	0.777	0.42	0.25	0.5	2.518
3	0.42	0.444	0.21	0.5	1	2.574
4	0.28	1	0	0.75	0.77	2.8
5	1	0.222	0.14	0	0.166	1.528

The routing algorithm FLWMR considered only the metric is hop count and in FLWLAR metric is traffic load along the link are input to the fuzzy controller, based on these metrics fuzzy controller evaluates the fuzzy cost, but our proposed algorithm considers five characteristics of network to find the fuzzy cost. In FLWMR and FLWLAR fuzzy controller was designed base on nonlinear property where as our method introduced linearity when evaluating the fuzzy cost.

In unipath approaches like DSDV, AODV, and DSR the same node repeatedly utilized and hence it is subjected to higher resource exhaustion and over load. Even if the intermediate node changes its position, the routing protocol again initiates the RREQ [4] packet which is in turn lead to redundancy of broadcasting. To over come this problem, multi path routing protocols have been proposed. In this approach also, the traffic only on one route is examined because traffic load is not diverted into multiple routes. Then the distribution of traffic amongst the various routing paths effectively again a problem. In ImRMR [10], protocol the traffic is distributed amongst the best selected paths from the existing multipath routing the selection is based on consideration of five resource constraints bandwidth, computing efficiency, power consumption, traffic load, and the number of hops.

In ImRMR based on the available resources, the algorithm evaluates the rank for each path in the existing paths. Instead, our method determines the cost of each vector which is more helpful in the situation when more number of vectors have the same rank.

III. FUZZY COST BASED MULTI PATH ROUTING

In this protocol we are assuming that n paths will be exists from source to destination. The fuzzy cost of each path is based on the details of resources which include bandwidth, computing efficiency, power consumption, traffic load, and the number of hops. In rank vector approach, being the source used at each node the same resources; some paths have same rank which leads to confusion for data transfer. But fuzzy cost is unique for each path.

Let V is the set of vertices and E is the set of edges between any two set of nodes. The link edges between two nodes can be presented as

$$E_{ij} = E(i, j) = \begin{cases} 0 \\ 1 \end{cases}$$

Let n be the number of paths between source and destination, then collection of paths (vectors) in ImRMR, is represented as

$$\Pi = \{V_1, V_2, V_3, \ldots\ldots, V_n\}$$

Where V_i is i^{th} vector from source to destination and v_s and v_d are source and destination node then path represented from v_s to v_d as

$$V(v_s,v_d) = v_{i,j=1}^{\;i,j=n} = E(v_s,v_i) \wedge E(v_i,v_j) \wedge E(v_j,v_d)$$

3.1.1 Concept of Ranks

Ranking refers to the process of ordering a sample with respective to a system of performance metric. To minimize the complexity in the process, the observation with the least value of the objective function receives the highest rank while the observation with the maximum values receives the lower rank (i.e rank 1).Rank process will be failed in the situation of same objective function values(of resources) . Hence in this paper we proposed fuzzy cost.

3.1.2 Fuzzy concept in MANETs

The membership functions were introduced by Zadeh in the first paper on fuzzy sets (1965). A fuzzy set is a generalization of the indicator function in classical sets. Fuzzy logic represents the degree of truth as an extension of valuation. Degrees of truth are often confused with probabilities through they are conceptually distinct. Fuzzy truth represents membership in vaguely defined sets, not even the likelihood of some event or condition.

For any set X , a membership function on X is any function from X to the real unit interval [0,1]. Membership functions on X represent fuzzy subset of X. The membership function set is usually denoted by μA. For an element x of X, The value μA(*x*) is called the member ship degree of x in the fuzzy set. $\mu_A(x)$ quantifies the grade of membership of the element x to the fuzzy set. $\mu_A(x)$ =0 means that x is not a member of fuzzyset. The value of $\mu_A(x)$=1 means that x is fully member of fuzzy set .The value of $\mu_A(x)$ between 0 and 1 charctrize fuzzy members , which belong to set partially.

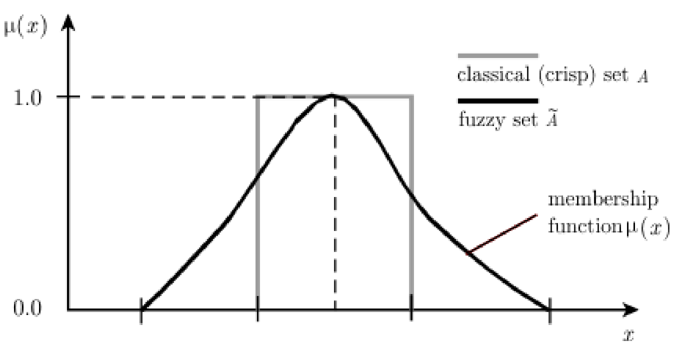

Fig 1 Relation Ship diagram between Crisp and Fuzzy

3.1.3 Fuzzy Cost Evaluation for Resource Vectors

3.1.3.1 Fuzzyfication

It is a process of converting characteristics of network (i.e. node or link) in to fuzzy measure by using characteristic functions in 1 & 2.

Fuzzy cost will be evaluated by applying fuzzy measure function μ to the resources. It maps the resource values in to 0 to 1 interval based on favorable or not favorable resource for routing. M_i is resource vector corresponding cost vector is C_i will be calculated by applying fuzzy measure μ.The above process also calling as fuzzyfication in the literature of fuzzy.

3.1.3.2 Fuzzy cost Evaluation

Let M_i is resource vector (λ_1^i ,λ_2^i ,λ_3^i ,……. λ_k^i) here we consider k number of resources some of them are favorable for routing and some are not favorable for routing for example available band width is favorable for routing and traffic is not favorable for routing.

Several metrics have been chosen to meet these objectives and to produce a single cost metric (C) for selecting routes. The various routing metrics used are: bandwidth, computing efficiency, power consumption, traffic load, and the number of hops

$$C= f(BD,N,TL,PC)$$

In this protocol we defined C is linear function which is defined in equation (1) & (2).

The band width calculating function is defined as:

$$BD_F^{(I)} = BD_T^{(I)} - (BD^{(I)}_U + BD^{(x)}_M)$$

According to our band width calculation function, a mobile device can keep at least BD_F amount of bandwidth. Only the remaining free bandwidth can be used to serve another routing path with a required band width B_M , making the node join the other path as an intermediate node. In other words, the bandwidth, B_F , is reserved for the mobile device and the bandwidth embedded in a device will not be all occupied during the discovery of routing path.

The computing efficiency function is computed as follows

$$E_I = 1/ n \Sigma_{x=1}^{n} T_l^{(x)} = 1/n \Sigma_{x=1}^{n} S_M^{(x)} / C_l$$

Assuming that the distance between the transmitter node and the receiver node is d, the strength of the signal received can be determined using the following equation.

$$Pr(d) = (P_t \; G t \; G r \; \lambda^2) / (4\Pi)^2 d^2 \; L$$

Where Pr(d) is the received power. Assuming P_t is the transmitted power, and the transmitter antenna gain denotes as G t, Gr is the receiver antenna gain. L is the system loss factor. λ is the wave length in meters. It is also assumed that the received power is related to the distance between the transmitter and receiver.

TABLE III
THE COST VALUES FOR ALLOTTED RESOURCES ALONG WITH RANK

Vector	Bandwidth	Comp Efficiency	Power Cons	Traffic Load	No of Inter nodes	Total Vector cost
1	60	400	50	0	4	3.018
2	40	350	40	3	3	2.518
3	30	200	55	2	1	2.574
4	20	450	70	1	2	2.8
5	70	100	60	4	5	1.528

3.1.3.3 Fuzzy Controller

In the proposed paper fuzzy controller [16] will take the five inputs base on the following equations controller will give the fuzzy cost. The equations which are used to find cost were satisfying linearity property.

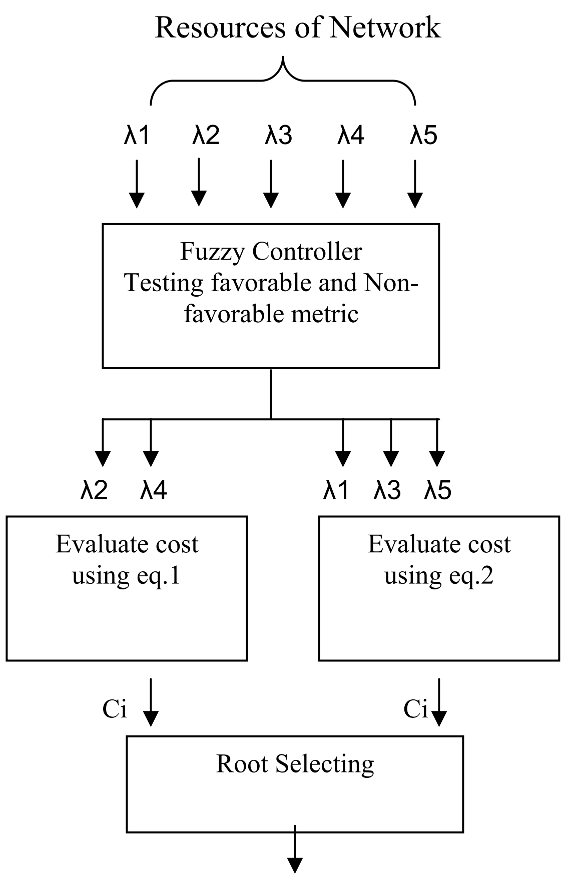

Fig 2 Fuzzy Controller

The core part of the algorithm design is fuzzy controller [16]. It is designed based on linear equations. The linear equations are classified in to two categories one is favorable and another is non favorable equation. The equations are used based on the input values.

Let $\lambda_p^{\,i}$ is favorable then

$C^{p}_{i} = \mu\,(v_i(M_i(\lambda p)\,)) = v_i(M_i(\lambda p)) / \max\{ vi(Mi(\lambda p)) \}^{n}_{i=1}$ -----(1)

and $\lambda_q^{\,i}$ is not favorable then

$C^{p}_{i} = \mu\,(v_i(M_i(\lambda p)) = 1 - v_i(M_i(\lambda p)) / \max\{ vi(Mi(\lambda p)) \}^{n}_{i=1}$ ---(2)

3.1.3.4 Fuzzy cost based Multi path Routing Algorithm

Input: A set of resource vectors $\{M_1, M_2, M_3, \ldots, M_n\}$ indicating set of path vectors $\{V_1, V_2, V_3, \ldots\ldots, V_n\}$

Output: The reorder set of resource vectors with $\{M_{c1}, M_{c2}, M_{c3}, \ldots\ldots, M_{cmax}\}$ with the assigned fitness value of each M_i based which indicates $\{V_{c1}, V_{c2}, V_{c3}, \ldots, V_{cmax}\}$

Method:

```
for each i from 1 to n
    for each p from 1 to maximum resources (k)
        if p is favorable
          {

            Ci^p  =  Vi(Mi(λp)) /  max { vi (λp)}  n i=1
          }

          else
            {
          Ci^p  = 1 -  Vi(Mi(λp)) /  max { vi (λp)}  n i=1
            }

   for each i from 1 to n
     {
       for each p from 1 to k
          cost = Ci ^p   + cost

          cost[i] =cost ;
     }
```

The above algorithm evaluates and assigns fuzzy cost to each vector. The threshold value of fuzzy cost will be predefined the paths with fuzzy cost more than threshold will be consider for sending data form source to destination

Consider an example destination node receives five messages from the source node it means five paths will be exist form source to destination. The information recorded in each node can thus form a vector index. Assumed that these four vector indexes are (60, 400, 50, 0, 4), (40, 350, 40, 3, 3), (30, 200, 55, 2, 1), (20, 450, 70, 1, 2), (70, 100, 60, 4, 5) the interpretation of values represented in table 1

The value of bandwidth field records the bottleneck band width which can be sustained in this routing path. Additionally, the value of computing efficiency is the bottleneck computing performance supported. The value of the traffic load records that the maximum number of route repeatedly utilizing and intermediate node in this designated routing path. Larger values of the supported bandwidth and the computing efficiency are preferable. On the other side smaller values of traffic load, the power consumption, and less number of intermediate nodes are desirable. Fuzzy cost evaluation for vector according to the formulas (1) & (2)

According to our proposed fuzzy cost based routing algorithm each vector is assigned a fuzzy cost shown in table 2.

Fuzzy cost of each vector is represented in Table 3, on the other way, the DSR and AODV protocols take the routing decision according to the number of intermediate nodes consideration only but our fuzzy cost based multi path routing ting protocol takes the routing decision by considering predefined fuzzy cost threshold value it is defined depend on the requirement of number of paths.

IV. Implementation Details

In the proposed protocol we are applying fuzzy cost based multi path routing algorithm to On Demand Multicast Routing Protocol (ODMRP) [14]. We implemented the proposed protocol with glomosim-2.03 [7] library is scalable simulation environment for wireless network system using the parallel discrete-event simulation capability provided by PARSEC [11]. Our simulation model a network of 30 mobile hosts placed randomly with in a 2000m X 2000m. Radio propagation rang for each node was 250meters and channel capacity was 2 Mbits/sec.There were no network part ions throughout the simulation. Each simulation executed for 600sec.

V. Proposed Protocol Performance

We compared our proposed protocol performance measures with existing ODMRP with and without fuzzy cost. We compared join queries and join reply with pause time in both our proposed protocol and ODMRP packet delivery ratio is compared with AODV protocol. We also compared signal send and receive power in both proposed protocol and ODMRP with pause time.

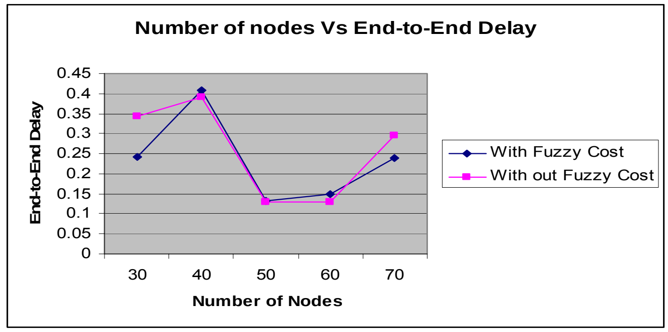

Fig 3 Number of Nodes Vs End-to-End Delay

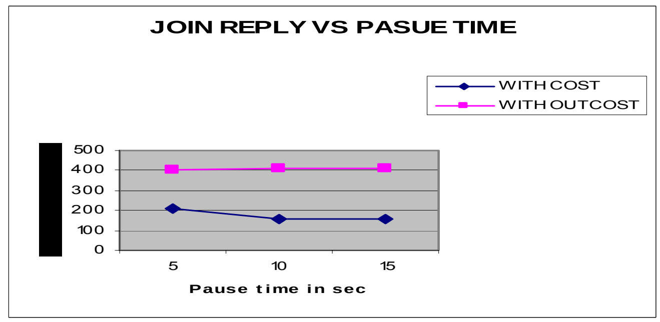

Fig 4 Join Reply Vs Pause Time

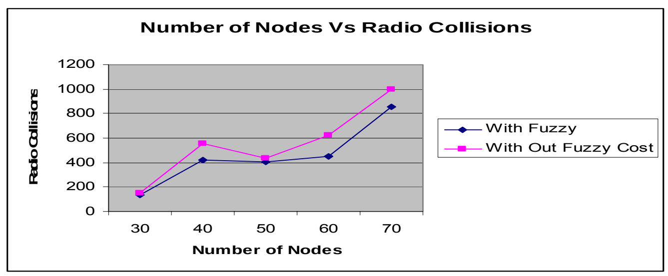

Fig 5 Number of Nodes Vs Radio Collisions

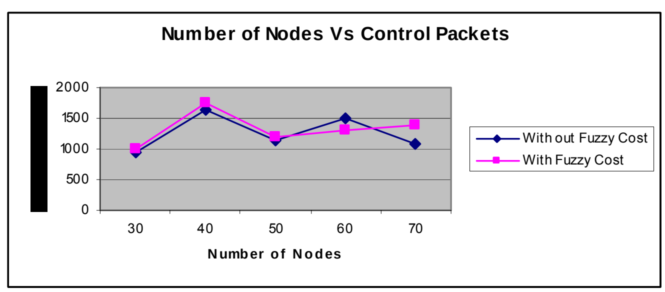

Fig 6 Number of Nodes Vs Control Packets

VI. Conclusions

In this paper, we have introduced Fuzzy cost based approach to select the effective paths among from existing multi paths. It is felt that our proposed protocol is more helpful and meaningful when there is a problem of redundancy of traffic load and there is same rank for several paths, since fuzzy cost is determined uniquely for each path.

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