A Fuzzy Based Distributed Approach to Maintain Connectivity of Nodes in Mobile Ad-Hoc Networks

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Abstract: The highly dynamic character of a Mobile Ad-Hoc Network (MANET) poses significant challenges on network communications. Previous work on MANET has resulted in numerous routing protocols aiming to maintain network connectivity among the active nodes. This paper presents a fuzzy based distributed algorithm to maintain connectivity in MANET. According to the algorithm each node will control itself so that it can maintain its connectivity with all other nodes. In this approach each node is enabled with a GPS receiver. All the nodes in a network transmit their position and velocity information periodically. Obtaining this information from all other nodes each node will decide its own velocity to maintain connectivity. Results obtained through simulation studies show the correctness of the proposed algorithm.

Keywords: Mobile Ad-hoc Network, Distributed Algorithm, Connectivity Maintenance, Fuzzy Logic

I. INTRODUCTION

A mobile ad-hoc network (MANET) is a collection of mobile nodes, which communicate with each other without the support of established infrastructure [1, 7]. These networks have an important advantage that they do not require any existing infrastructure or central administration. Therefore, mobile ad-hoc networks are suitable for temporary communication links. Applications include emergency search and rescue operations, deployment of sensors, conferences, exhibitions where construction of infrastructure is difficult or expensive. Ad-hoc networks form self-organizing architecture that are rapidly deployable and that are adaptable to the propagation conditions and mobility pattern of the network nodes. In mobile Ad-hoc network there are no fixed routers-instead each node acts as a router as well as a host [1, 3].

In case of wireless networks there is always a base station, which reaches out to destination nodes, but in case of ad-hoc networks a mobile node may be out of range of transmission of the source node emitting packets. Besides a frequent cause of network disruption may be due to the transmission losses, which occur due to several natural phenomena. . This makes routing an essential requirement in MANET. The current focus of many researchers is to find an efficient routing protocol, which will ensure node connectivity whenever required without much delay and unnecessary overhead.

The primary goal of such an ad-hoc network routing protocol is to establish route efficiently. Route construction should be done with a minimum of overhead and bandwidth consumption. But route can only be formed if and only if the nodes are within the range of single of multi-hop communication range. There are different types of routing topologies including DSDV, CGSR, WRP, AODV, and DSR, ABR etc [2, 4, 5, and 9].

Recent research has addressed many aspects of MANET operation and management, including routing, multicasting, media access protocols, distributed service discovery etc. In these areas an overarching concern is mobility. The impact of mobility is severe on several protocols, which work, well in traditional fixed (wired) networks. As a result, scalability is affected in networks with a large number of communicating pairs of nodes. To maintain routing scalability in spite of mobility, a possible approach is to exploit motion affinity. Centralized topology management schemes in [1, 3, and 6] discuss a self-adaptive movement control algorithm; this gives an idea for topology management. In [8, 10] distributed connectivity maintenance schemes are discussed assuming that all the nodes are moving in the same direction.

In this paper we are going to present one fuzzy based distributed algorithm for maintaining connectivity of nodes assuming unidirectional movement of the nodes. For routing we can use any existing scheme but routing is possible if all the nodes remain connected during their movement. In this paper, we have suggested a distributed algorithm, which ensures that all the nodes of the network will remain connected during movement to overcome the problem of loss of connectivity.

The paper is organized as follows. Next section provides the formal definition of the problem statement along with some parameter definition. We present the proposed distributed algorithm for maintaining the connectivity in section III. Simulation results are presented in the section IV. We finally conclude the paper in section

II. PROBLEM & PARAMETER DEFINITION

In MANET all the nodes are mobile, so the problem is to control the movements of the individual nodes so as to maintain a connected network at every instant of time to allow the nodes to communicate amongst them.

Initially all the nodes will have to maintain minimum distance from the front most node. This distance is called

SAFE distance ('RSAFE') though maximum communication range is greater than safe distance and this maximum communication range is denoted as 'R MAX' as shown in figure-1.

Each and every node will broadcast their velocity and position information after a period of time interval. This interval is termed as beacon interval, which is denoted as 'T'. Beacon interval is chosen (R MAX – RSAFE) / 2 VMAX. The proof for choosing beacon interval is shown in lemma in the appendix.

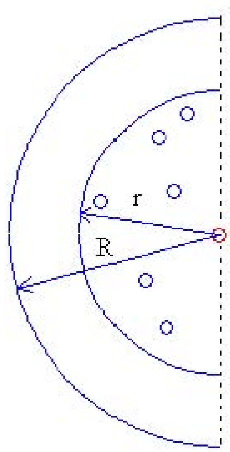

Figure 1: 'r' is safe distance and 'R' is maximum communication range.

III. THE PROPOSED ALGORITHM

Assumptions:

1. There is predefined maximum communication range (R MAX), predefined safe distance (RSAFE) and maximum velocity (VMAX)
2. All nodes broadcast its position and velocity information periodically. This period is termed as beacon interval (T) and. T < (R MAX – RSAFE) / 2 Y MAX.
3. All the received information from other nodes is correct.
4. Initially all the nodes must form a connected graph with the front most node and maximum length of the cord of that connected graph will be SAFE' amount.

Algorithm:

In this paper a fuzzy based connectivity maintenance algorithm is introduced. This algorithm maintains connectivity of nodes in MANET. The input variables are distance and velocity. Crisp input values are changed to fuzzy variable small, medium and large. The membership functions are considered to be triangular shaped as shown in the figure-2 and figure-3.These functions are used to fuzzify the input variables.

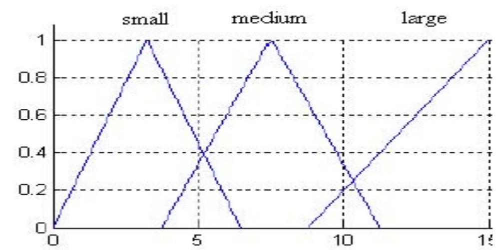

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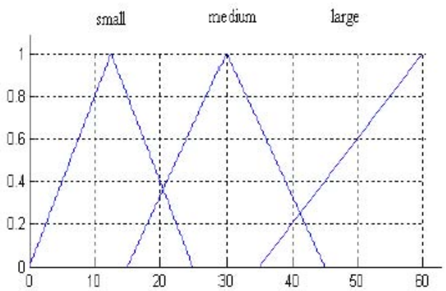
Figure 2: Membership function for fuzzyfication of 'distance'



1. All the nodes are enabled with GPS receiver.

Figure 3: Membership function for fuzzyfication of 'velocity'

2

Now we shall use the following fuzzy rule base: movement and path traversed by each and every

node is

shown graphically. ***RULE1:*** If 'distance' is 'small' and the velocity is 'small' then velocity in the next beacon interval is

A. Sample – I: 'small'.

RULE2: If 'distance' is 'small' and the velocity is 'medium' then velocity in the next beacon interval is 'small'.

RULE3: If 'distance' is 'small' and the velocity is 'large' then velocity in the next beacon interval is 'medium'.

RULE4: If 'distance' is 'medium' and the velocity is 'small' then velocity in the next beacon interval

	Position (KM)	Velocity (KMPH)	
	X		Y
Node 1	0	-0.5	50
Node 2	1	1	25
Node 3	0.5	0	36
Node 4	1.5	1.5	21
Node 5	-0.5	1.8	52

is 'medium'.

RULE5: If 'distance' is 'medium' and the velocity is 'medium' then velocity in the next beacon

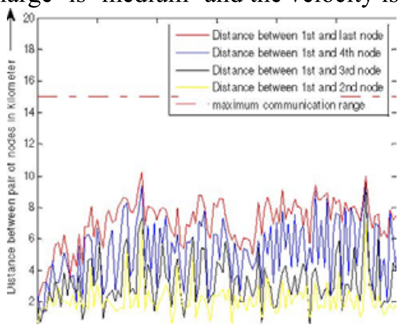
20 18 16 14 12 10 8

6

Dis tanc e between pair of nodes in k ilom eter

4 2

RULE8: If 'large' is 'medium' and the velocity is



0
is 'large'. 'medium' then velocity in the next beacon interval 0 50 100 150 200 250 Time in minutes Figure 4: Distances from node-1 for sample-I ***RULE9:*** If 'distance' is 'large' and the velocity is 'large' then velocity in the next beacon interval is *B. Sample – II:* 'large'.

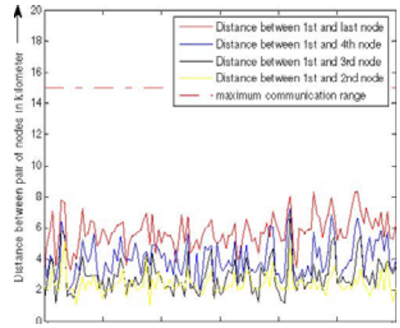
interval is 'medium'.
RULE6: If 'distance' is 'medium' and the velocity is 'large' then velocity in the next beacon interval is 'large'.
RULE7: If 'distance' is 'large' and the velocity is 'small' then velocity in the next beacon interval is 'large'.

In the fuzzy rule base minimum membership function is considered. If more than one rule fire then maximum membership function is considered.

Now for defuzzification: if output fuzzy variable is large then actual final velocity will be calculated using speed= (70 + membership function x 50) otherwise it will take random velocity within

	Position (KM)	Velocity (KMPH)	
	X	Y	
Node 1	0	1	31
Node 2	2	1	21
Node 3	2	2	10
Node 4	0	0	5
Node 5	3	3	41

the range of 60km / hr.
safe distance 'RSAFE'=10km. So, the beacon interval is (15-10) / 2 x 60 hr. i.e. 2.5 minutes. Simulation is 0 50 100 150 200 250 carried out for three different sample network Time in minutes scenarios. For each sample network initial and final position of the nodes, velocity changes during Figure5: Distances from node-1 for sample-II



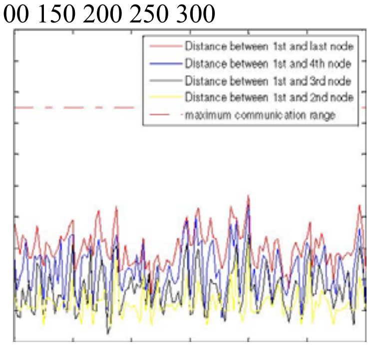
IV. SIMULATION RESULTS

We simulated the algorithm assuming a hypothetical network using Mat lab software in Windows environment and obtained encouraging results. For our simulation we considered five nodes and the system parameters maximum communication range 'RMAX' = 15km, maximum allowable preferred velocity 'VMAX' = 60km / hr,

C. Sample –III: International Mobile Computing Conference 2006,

	Position (KM)	Velocity (KMPH)	
	X	Y	
Node 1	1	3	37
Node 2	3	2	29
Node 3	4	3	21
Node 4	5	1	56
Node 5	8	0	12

Dis tanc e between pair of nodes in k ilom eter
20 18 16 14 12 10 8 6 4 2
0 0 50 100 150 200 250 300



Time in minutes

Figure 6: Distances from node-1 for sample-III

CONCLUSION

In this paper, we have introduced a fuzzy based distributive algorithm for mobile nodes in MANETs for maintaining connectivity considering uni-directional movement. Due to the distributed scheme the topology is not vulnerable if one of the nodes becomes non-functional, as there is no concept of coordinator. This algorithm maintains connectivity without any control message, which is essential in the case of centralized approach. Results from simulation study are encouraging.

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APPENDIX

VR***Lemma:*** If maximum communication range is 'R MAX' and safe distance is 'RSAFE', where R MAX > SAFE, maximum preferred velocity 'VMAX', now if we choose beacon interval T ≤(R MAX– RSAFE) / 2 MAX, then there is no chance for the nodes to go out of the communication range.

V***Proof:*** Maximum preferred velocity of a node is MAX. So the maximum possible relative velocity between two nodes is 2 VMAX, when they are in opposite direction. So the maximum relative distance traveled in a beacon interval is 2T VMAX. Since initially maximum separation between two nodes may be 'RSAFE', so a neighbor node cannot become an non-connected node if

$$2T\ VMAX \leq (R\ MAX - RSAFE)$$

$$\text{Or, } T \leq (R\ MAX - RSAFE) / 2\ VMAX$$