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# A FUZZY BASED DISTRIBUTED NODE MOVEMENT ALGORITHM FOR MAINTAINING NEIGHBORHOOD TOPOLOGY IN MOBILE AD-HOC NETWORKS

**Jishan Mehedi* & M. K. Naskar****

This paper proposes one scheme for selecting neighborhood and fuzzy based distributed movement algorithm for maintaining neighborhood topology during movement of the network. All the nodes are enabled with GPS. All the nodes will periodically broadcast their position and velocity information obtained through the GPS. After receiving the information from the other nodes, a node will first decides its neighboring nodes. Once neighborhood selection is done, the whole network will start their movement. During movement, each and every node is responsible to maintain its initial neighborhood intact. The key concept in this algorithm is that in each and every beacon interval node will decides its movement, so that it can maintain connectivity with its maximum distant neighbor. And this decision is fuzzy logic based. We have simulated the algorithm in a number of synthetically designed situations and the results we have obtained have been quite encouraging.

***Keywords:*** MANET, Topology Management, Fuzzy Logic, Distributed Algorithm.

## 1. Introduction

Mobile Ad-hoc Network (MANET) is a self-configured network consists of mobile nodes to form wireless network architecture [1]. MANET does not require any established infrastructure of central administration [2, 3]. Node mobility in an ad-hoc network causes frequent changes of the networks topology. Thus routing is needed to find the path between source and destination and to forward the packets appropriately. Hence, in case of ad-hoc networks the nodes not only behave as usual trans-receivers but also as routers [2]. Mobile ad-hoc networks are extensively used to retain connectivity of nodes in inhospitable terrains. It is also projected to play significant roles in network maintenance in case of disaster relief, search-and-rescue operations, military activities, unplanned meetings, spontaneous interpersonal communication etc. where preconceived infrastructure is absent and sudden data acquisition is necessary [4, 5]. Random node movement makes routing an essential requirement for MANET. Hence, the current focus of many researchers is to find out an efficient routing protocol which ensures node connectivity whenever required without much delay and unnecessary overhead. The two widely accepted approaches for topology management are centralized and distributed algorithms [2]. Centralized topology management schemes in [2, 5] discuss a self-adaptive movement control algorithm which ensures the retention of network connectivity even during the positional variation of the nodes. Topology management scheme discussed in [2, 5] is centralized and the movement of the whole network is controlled by central coordinator. So in those two schemes if the coordinator fails, then whole network will fail. More over only unidirectional movement has been considered in those two schemes. Distributed scheme [6] for connectivity maintenance considering omni directional movement of the nodes suffers from the disadvantage of rapid velocity changes in emergency situations. This hampers the stability of the nodes. In this paper we are going to present distributed fuzzy control movement algorithm for maintaining connectivity to reduce the rapid velocity changes, thereby to improve the stability of the nodes. The rest of the paper is organized as follows. Next section provides the formal definition of the problem, few parameter definitions and the concept of neighborhood topology. In section-3 we present lemma for choosing beacon interval. Section-4 presents the proposed algorithm. Section-5 reports the effectiveness of our algorithm with simulation results. Finally, we offer our concluding remarks in Section 6.

* Department of Electronics & Communication Engineering, NIT, Silchar, Silchar, INDIA. *E-mail: jmehedi2007@yahoo.co.in*

** Department of Electronics & Telecommunication Engineering, Jadavpur University, Kolkata, INDIA
*E-mail: mrinalnaskar@yahoo.co.in*

## 2. Topology Management Problem and Few Parameter Definitions

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

### 2.1 Definition of Few Parameters and their Notations

*Maximum Communication Range:* It is the maximum distance through which two nodes can communicate among them. It is denoted in the remaining section as ‘$R_{max}$’.

*Threshold Distance:* We define a distance as threshold distance, which is less than maximum communication range. This distance is denoted as ‘$R_{th}$’.

*Beacon Interval:* the amount of time interval after which all the nodes periodically broadcast their updated position and velocity information is known as beacon interval, denoted as ‘$T$’.

### 2.2 Concept of Neighborhood Topology

The nodes which are within the range of threshold distance from a particular node is said to be the neighbors of that particular node. The basic philosophy behind the proposed algorithm is to maintain initial neighborhood topology during the entire movement of the nodes. Node no-1, 2, 3, 4, 6 and 9 are neighbors of node no. 5. Similarly node no.- 4, 5, 6, 7, 8, 10 and 11are neighbors of node no. 9 as shown in Figure 1.

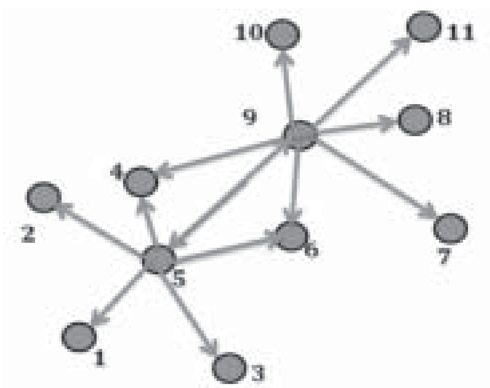


**Figure 1: Demonstrating Neighborhood Topology**

### 2.3 Topology Management Problem

Let us consider a system of $n$ nodes ($n_0$, $n_1$ …. $n_{n-1}$) constituting a MANET. Among them two nodes $n_i$ and $n_j$ are said to be neighboring if and only if they can communicate without the need of routing. Now if we assume that the transmission range of each node be $R_{max}$ and $D_{ij}$ denotes the relative distance between the nodes then the network neighborhood topology will be maintained provided there is at least one $j$ such that

$$D_{ij} \leq R_{max} \ \forall \ i, j = 0, 1, 2 \ldots. n-1$$

## 3. LEMMA FOR CHOOSING ‘BEACON INTERVAL’

**Lemma:** If maximum communication range is ‘$R_{max}$’ and the threshold distance is ‘$R_{th}$’, where $R_{max} > R_{th}$, maximum predefined velocity ‘$V_{max}$’, now if we choose beacon interval $T \leq (R_{max}-R_{th}) / 2\ V_{max}$, then there is no chance for the nodes to go out of the communication range.

**Proof:** Maximum predefined velocity of a node is $V_{max}$. So the maximum possible relative velocity between two nodes is 2. $V_{max}$, when they are in opposite direction. So the maximum relative distance traveled in a beacon interval is $2T\ V_{max}$. Since initially maximum separation between two nodes may be ‘$R_{th}$’, so a connected node cannot become an non-connected node

$$\text{If, } 2.\ T.\ V_{max} \leq (R_{max}-R_{th})$$

$$\text{Or, } T \leq (R_{max}-R_{th}) / 2\ V_{max} \quad (1)$$

## 4. ALGORITHM

In this section we are going to propose our fuzzy based node movement algorithm for maintaining a connected topology throughout the entire movement of the network. Our proposed algorithm can be divided into two parts: i) Neighborhood Selection and ii) Movement Algorithm.

### 4.1 Definition of Few Parameters and their Notations

i) Initially the network must be a connected one.

ii) Each node is enabled with a GPS receiver.

iii) Every node has a predefined maximum velocity, $V_{max}$.

iv) Each node has its own identification number.

### 4.2 Neighborhood Selection

Initially, all the nodes will broadcast their positional information. Positional information is obtained through the GPS. Now all the nodes will receive positional information of the nodes, which are within the maximum communication range. Now each and every node can easily calculate its distances from other nodes, which are within the maximum communication range. Neighborhood selection is very simple one. Fuzzy logic has not been incorporated here. Threshold distance is defined in the section-2.1 and the concept of neighborhood topology is also discussed in the section-2.2. After calculating the distances each and every node will find their neighbors. In the next section one distributed movement algorithm scheme is suggested to maintain the initial neighborhood topology intact during the entire movement of the network.

### 4.3 Movement Algorithm

Movement algorithm is distributed and fuzzy logic based. The concept of ‘Coordinator’ is not there. So each and every node in the neighborhood topology is responsible to maintain the connected topology during movement of the nodes. Algorithm is illustrated in the following sections.

#### *4.3.1 Fuzzy Logic Control*

We are going to propose fuzzy logic based algorithm for movement of the nodes. The model of fuzzy logic control consists of a fuzzifier, fuzzy rules, fuzzy inference engine, and a defuzzifier. We have used the most commonly used fuzzy inference technique called Mamdani Method due to its simplicity. The process is performed in four steps:

- Fuzzification of the input variables the distance from the maximum distanced neighbor, velocity of the node in consideration - taking the crisp inputs from each of these and determining the degree to which these inputs belong to each of the appropriate fuzzy sets.
- Rule evaluation–taking the fuzzified inputs, and applying them to the antecedents of the fuzzy rules. (Table 2, 3 and 4).
- Aggregation of the rule outputs–the process of unification of the outputs of all rules.
- Defuzzification–the input for the defuzzification process is the aggregate output fuzzy set modulated velocity and the output is a single crisp number. During defuzzification, we have adapted Weighted Average method. The weighted average method is formed by weighting each membership function in the output by its respective maximum membership value. The algebraic expression is given in equation-2.

$$\bar{x} = \frac{\sum_i \mu_i(x).c_i}{\sum_i \mu_i(x)} \tag{2}$$

Where $\mu_i(x)$ is the membership value, $c_i$ is the weight and $\bar{x}$ is the defuzzified crisp value.

#### *4.3.2. Expert Knowledge Representation*

Expert knowledge is represented based on the following three descriptors:

- Distance from the maximum distanced neighbor–the value is calculated from the node in consideration as discussed in the earlier section, designated by the fuzzy variable distance.
- Velocity of the node–the value is directly received through GPS, designated by the fuzzy variable velocity.

The linguistic variables used to represent the distance from the maximum distanced neighbor has five levels: very small (*VS*), small (*S*), medium (*M*), high (*H*) and very high (*VH*), velocity is divided into five levels: very small (*VS*), small (*S*), medium (*M*), large (*L*) and very large (*VL*). The velocity of the node for next beacon interval is divided into five levels: very small (*VS*), small (*S*), medium (*M*), large (*L*) and very large (*VL*). Thus we used $5^2 = 25$ if then rules for the fuzzy rule base. The rule base is shown in Table 1. The membership functions developed and their corresponding linguistic states are represented in Figures 2 through 4.

**Table 1**
**Fuzzy Inference Rules for Movement Control**

| *Distance* *Velocity* | *VS* | *S* | *M* | *H* | *VH* |
|---|---|---|---|---|---|
| VS | VS | VS | S | S | M |
| S | VS | VS | S | M | M |
| M | S | S | M | L | L |
| L | M | M | M | VL | VL |
| VL | M | L | L | VL | VL |

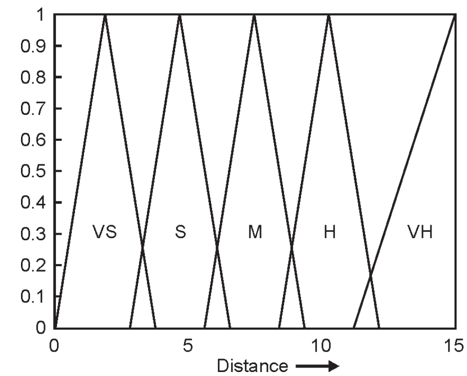

**Figure 2: Fuzzy Set for Fuzzy Variable, 'Distance'**

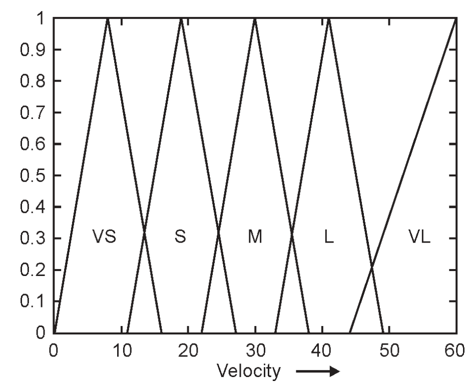

**Figure 3: Fuzzy Set for Fuzzy Variable, 'Velocity'**

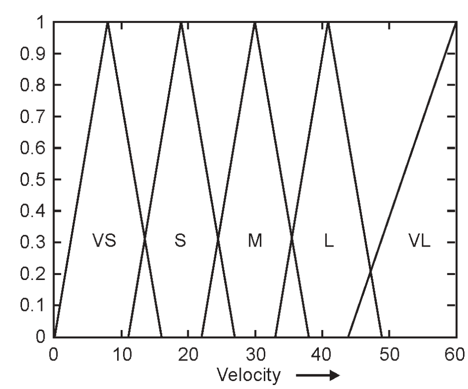

**Figure 4: Fuzzy Set for Fuzzy Variable, 'Velocity for the Next Beacon Interval'**

### *4.3.3 Formal Representation of Algorithm*

**Step-1:** Broadcasting of positional information obtained through GPS by all the nodes.

**Step-2:** Receive the information from the other possible nodes.

**Step-3:** Depending on the received information, calculation of the distances from other nodes is done.

**Step-4:** Selection of neighbors of all the nodes are done by satisfying the following condition: the nodes whose distances are less than or equal to the threshold distance, are the neighbors of that particular node.

**Step-5:** Broadcasting of positional information obtained through GPS by all the nodes.

**Step-6:** Information is received by all the neighbor nodes.

**Step-7:** Each node will now calculate the distance from the farthest neighbor. Crisp value of this distance and the velocity of the node are converted to a fuzzy variable.

**Step-8:** Fuzzy rule base is called with fuzzy distance, fuzzy velocity.

**Step-9:** Fuzzy movement decision obtained from the fuzzy rule base is defuzzified and crisp decision is obtained.

**Step-10:** Allow all nodes to move for one beacon interval according to their decision.

**Step-11:** Go to step 5

## 5. SIMULATION RESULTS

To test and analyze the effectiveness of the algorithm, experimental studies were performed. The simulator was programmed using MATLAB in Windows environment. The algorithm is simulated taking maximum communication range '$R_{max}$' = 15 KM, maximum velocity of nodes, '$V_{max}$' = 60 KM / hr. So, beacon interval = 2.5 minutes. Simulation is carried out for different sample networks for different number of nodes for different simulation time ranging from 1 hr. to 25 hr. But for the simplicity and clarity of graphical representation, simulation result with six nodes for two hour is shown. Initial and final position of the nodes, velocity changes during movement of the nodes and path traversed by the nodes are shown graphically for sample networks.

### 5.1 Sample Network

The network is of six nodes and their initial coordinates are (0, 5), (-2, 2), (3, 0), (1, 4), (-2, -2), and (3, -3) respectively

From the above simulation result it is now clear that the scheme proposed by us is capable of maintaining topology of the network during the entire movement of the nodes considering omni- directional movement of the nodes.

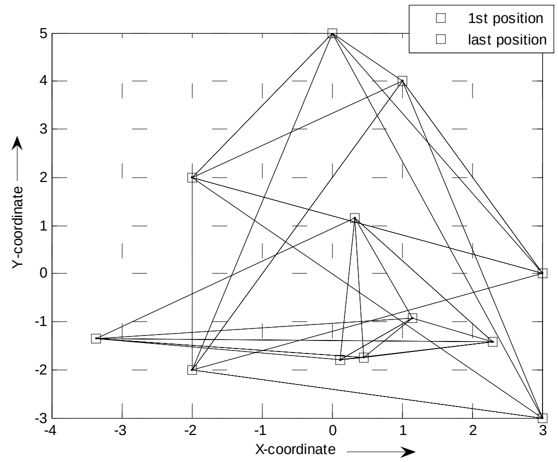


**Figure 5: Initial and Final Position of the Nodes for Sample Network-1**

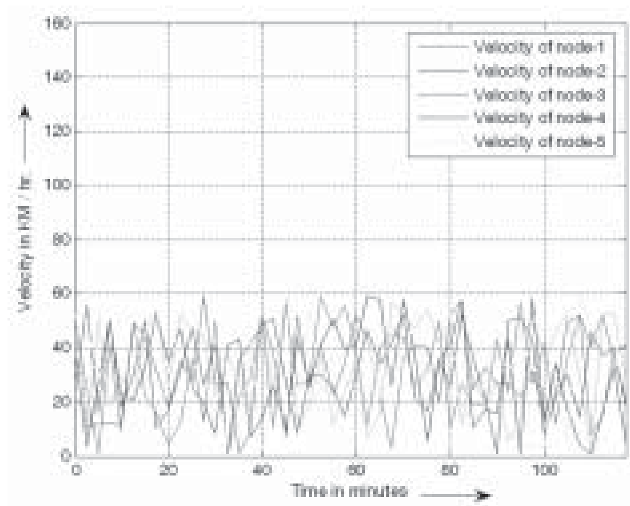


**Figure 6: Velocity Changes of the Nodes for Sample Network-1**

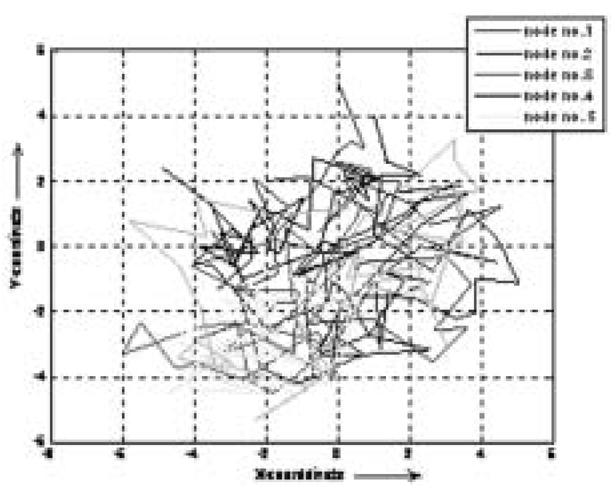

**Figure 7: Path Traversed by Different Nodes for Sample Network-1**

## 6. CONCLUSION

In this paper, we have introduced a distributive fuzzy logic based algorithm for mobile nodes in MANETs for maintaining neighborhood topology considering omni 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. Since initial neighborhood topology is maintained throughout the entire movement of the network, so there is no need to update routing table. So routing overhead is also eliminated. Movement of the nodes is based on fuzzy logic based. So, in this algorithm MANET node is becoming more intelligent as compared to the nodes in algorithm [6]. Fuzzy logic is flexible; it can be built on top of the expert knowledge, mixed with conventional control methods and easy to add or change functionality. Simulation results demonstrate that the algorithm is able to maintain connectivity in Mobile Ad-hoc Networks (MANETs) efficiently. Now we are trying for hardware implementation our scheme. In future, we shall try to incorporate fuzzy logic combined with neural networks, so that the nodes can be trained with examples or can learn at runtime from feedback.

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