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FUZZY BASED CLUSTERING ALGORITHM FOR MANETS

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ABSTRACT

Mobile Ad Hoc Networks are known to be dynamic in nature and have no rigid or reliable network infrastructure by their very definition. They are expected to be self-governed and have dynamic wireless links which are not entirely reliable in terms of connectivity and security. In this paper, we aim to divide the network into cluster to achieve better stability and scalability. Several parameters could assist the reliability of the clusters and which could result in nodes being elected as a cluster head i.e. Node Mobility, Node Degree, Distance of Node, which in turn could impact the performance of the entire network. We propose Fuzzy C means to obtain the optimal number of clusters by using fuzzy membership functions for decision making in the cluster election. We have done the simulation using MATLAB and trimf membership function. The results indicate that the Node Mobility has the most powerful influence on determination of the cluster head.

INTRODUCTION

A Mobile Ad hoc Network is comprised of nodes connected by wireless links. By its very definition, formation and deformation, ad hoc networks need to be very dynamic in nature, more often than not unable to rely on a fixed communication infrastructure. Besides, such networks are also characterized and constrained by lack of resources such as battery power, lack of bandwidth and very limited security since defining a physical boundary is not practicable and Wireless Radio frequencies are open to anyone with the necessary resources and cannot be restricted. The mobile networking infrastructure therefore needs to be highly self-organizing and self-policing. Volatility in regard to the connectivity between nodes is a major factor in MANET research.

Clustering is a technique of grouping similar objects or data points into clusters based on some criteria, such as similarity, distance, density, etc. [1]. Clustering can be a useful technique with many applications in different areas of engineering [2]. Clustering in MANETs plays a pivotal role in improving network performance [3]. Clustering is physically broken the network down into several clusters each with a cluster head, cluster members and guests. cluster head is the local coordinator within the cluster. cluster head is elected by the cluster members on criteria such as Node Degree, Node Mobility, Distance of node, and Power Consumption.

Due to the routing overhead throughout the network, clustering would be the most important process to simplify the routing operation in Mobile ad hoc network. Several algorithms have been developed based on clustering [4]–[6]. In this paper, we propose fuzzy based clustering algorithm by deploying fuzzy C means based on a particular membership function to obtain the optimal number of clusters and to reduce the network overhead. Some aspects of our proposed input and output in different contexts have been analytically studied and simulated in the in the literature, but to the best of our knowledge, we did not find any other paper or article which simulates our combination of input conditions parameters i.e. Node Degree, Node Mobility, Distance of node, and Power Consumption and extracts output with an objective similar.

Ad hoc networks need to be very dynamic in nature, more often than not unable to rely on a fixed communication infrastructure. Besides, such networks are also characterized and constrained by lack of resources such as battery power, lack of bandwidth, and very limited security since defining a physical boundary is not practicable and wireless radio frequencies are open to anyone with the necessary resources and cannot be restricted [7], [8]. The mobile networking infrastructure therefore needs to be highly self-organizing and self-policing.

The mobile networking infrastructure therefore needs to be highly self-organizing and self-policing. Volatility in regard to the connectivity between nodes is a major factor in MANET research [9]. Connections are constantly made and broken at high speeds and frequencies, rendering certain tenets of communication and security impossible to implement. Node mobility and maintaining routes are two of the major challenges in securing ad hoc mobile networks, where both resulting in to packet drops, link breaks, and power consumption [10]. For this reason, it turns out that much of the research effort needs to focus on optimizing routes in ad hoc networks.

1. MOBILITY BASED CLUSTERING ALGORITHM.

Several studies have explored and documented the significance of clustering based on mobility metric.

1.1 Mobility-based Metric Clustering Algorithm

Generally speaking algorithms play a pivotal role in engineering as they encompass the fundamental processes of design, analysis, implementation, and optimization [11]–[13]. Chiara and Rath [4] have developed a distributed clustering algorithm. In this algorithm, the cluster head has elected based on nodes' movement. The node that has lowest mobility will assigned as a higher weight value and chosen as a cluster head. The role of cluster head is to distribute the time among its neighborhoods, where each node has a chance to act as a router. Therefore, this algorithm attempts to reduce the freezing time of motion for mobile nodes throughout the cluster by recording the previous actions of the movement of ever node, and predicting their average mobility to increase the lifetime of mobile device.

Basu and little [5] proposed a distributed clustering algorithm MOBIC. It is based on the lowest ID algorithm. They introduced a novel mobility metric in Ad hoc Mobile Network. The speed of the nodes measured relatively to other nodes, and the node with low speed comparing to their neighborhood will have an opportunity to be a cluster head. The mobility metric relied on the motion of nodes, and calculated the differences of the speed of the nodes and their members. Consequently, the aggregate speed can be estimated, and reduce the cluster head maintenance.

1.2 Mobility-based d-Hop Clustering Algorithm

This algorithm is based on d-hop [14]. It regulates variable diameter cluster based on the nodes' movement. The evaluation relied on the mobility metric, where the nodes that have similar motion pattern will be grouped in one cluster, and each node can measure its received signal strength. The calculation is based on diverse parameters such as the estimated distance and mobility between nodes, and the local stability. According to the estimated value, the nodes that have more stability will be elected as a cluster head.

1.3 Mobility Prediction-based Clustering Algorithm

This algorithm has been deployed to enhance the performance of the mobility prediction schemes [6]. Conducted the experiment based on Doppler shift and a serial of mobility-based clustering strategies. Each node estimates its average relative speed comparing to its neighbor members by broadcasting Hello Packets; therefore, the nodes with the lowest mobility are chosen as a cluster head. Prediction-based method takes a place to overcome the issues that caused by relative nodes' movement.

1.4 Clustering through Neighborhood Stability-based Mobility Prediction

A novel clustering algorithm which grants longer lifetime of clustering structure [15]. The main idea is to predict the mobility of each node based on the stability. They create a virtual backbone throughout the network by combining the mobility prediction scheme and the highest degree clustering technique. The node that has the highest weight in comparison to other nodes chosen as a cluster head. This algorithm overcomes the changing of the cluster head by allowing nodes to become a cluster head without initiating a re-clustering phase [16].

2. ENERGY-BASED CLUSTERING ALGORITHMS

2.1 Flexible Weighted Clustering Algorithm based on Battery Power

Hussein, Salem, and Yousef [17] introduced a flexible weighted clustering algorithm that guaranties a high degree of stability. The nodes with low battery power will be avoided of being a cluster head. Each node broadcasts a beacon message to create its neighbor list. Several factors are considered to compute the cluster head, the degree of nodes, distance summation, mobility, and remaining battery power. A node with lowest weight is selected as a cluster head.

2.2 Enhance Cluster-based Energy Conservation Algorithm

This algorithm is an enhancement of Cluster-based Energy Conservation, CEC [18] proposed a new topology control that increases the lifetime of ad hoc network and improves the performance in terms of energy consumption, A node is elected as a cluster head if it has the longest lifetime among its neighbors. The nodes can reach their neighbor and save the battery power by identifying redundant nodes and turning their radios off. The nodes can communicate with the cluster head without gateway or intermediate node [19].

2.3 Max-Heap Tree Algorithm based on Energy Efficient Clustering

Saxena, Phate, Mathai, and Rizvi [20] carried out Max-Heap tree algorithm to reduce the power consumption and provide a longer lifetime. The proposed algorithm is based on scalability and energy metric. During the implementation phase, an index number assigned to each node with respect of its energy level. The node with higher energy level will be the root of Max-Heap tree, and elected as a cluster head. The rest of nodes will be under the root node or cluster head. The nodes can communicate with the cluster head without gateway or intermediate node [21]–[23].

3. CONNECTIVITY BASED CLUSTERING ALGORITHMS

3. 1 High Connectivity Clustering

K-Hop Connectivity ID is a prototype of the distributed clustering algorithms. Mai and Choo presented Multi-Hop clustering and Non-overlapping scheme to achieve stability, reliability, and low maintenance. This algorithm concentrated on reducing re-clustering by setting a long distance between cluster heads; therefore, the probability that two cluster heads enter each other transmission is reduced [16]. Moreover, the transmission range among clusters become bigger. The reliability of clustering has been affected by connectivity where intra-connection and inter-connection where used as a metric to measure the connection quality between the cluster and jointly nodes. The cluster head is chosen based on the node that has the highest intra-connection degree.

3. 2 3-Hop between Adjacent Cluster head

In this mechanism Yu and Chong [24] proposed 3-Hop between adjacent cluster head, 3hBAC. During the cluster formation, a new node status named cluster guest. Cluster guest is unable to connect to any cluster head; however, it can be within the transmission range of cluster node members. The node with lowest ID and highest node degree is chosen as a first cluster head. Nodes that out of transmission range cannot participate as a cluster head; however, some neighbors are cluster member of some other cluster, those nodes will join the cluster as a cluster guest, this algorithm provides high robustness and reduce the number of cluster heads. Evaluating method relied on utilizing the Bayesian statistical analysis. They could reduce the search overhead based on nodes cooperation[25].

3. 3 Weighted Clustering Algorithms

Chatterjee, Das, and Turgut [26] proposed a flexible weight-based clustering algorithm takes advantages of several metrics in electing cluster head such as node degree, node mobility, and transmission power. Achieving load balancing by identifying a threshold on the number of node that cluster head can manage. The connectivity metric is based on inter-cluster communication and intra-cluster communication. Due to of combining such metrics in electing cluster head, WCA outperforms lowest ID algorithm in terms of power homogeneous and power heterogeneous networks.

4. SIGNIFICANCE

Due to the nature of mobile ad hoc network, routing is vulnerable to diverse kinks of threats. Enhancing security to Routing should ideally eliminate all such malicious behavior. Their formulation should result in creation of self-contained systems capable of early detection and early response to all possible types of attacks. Clustering is one of the proposed solutions has been developed for securing the routing in MANETs, it assists in reducing the complexity of managing nodes' information. However, it faces many challenges such as obtain the optimal cluster size, and cluster head [27]. To tackle the above problem and meet a better performance for secured routing, we introduce a new machine learning algorithm, Fuzzy C means in order to obtain the optimal number of clusters, and reduce the number of the re-election for the cluster head in terms of saving the network energy, and select the best cluster head throughout the network [28].

5. The Proposed System

We present our approach based on Fuzzy-Based System (FBS) to improve the Reliability and Stability of mobile nodes throughout the network as shown in Figure 1. Four input parameters have been taken in our consideration, Node Degree (ND), Node Mobility (NM), Nodes Distance (ND), Power Consumption (PC), where the output parameters are as Leave (L), Remain (R).

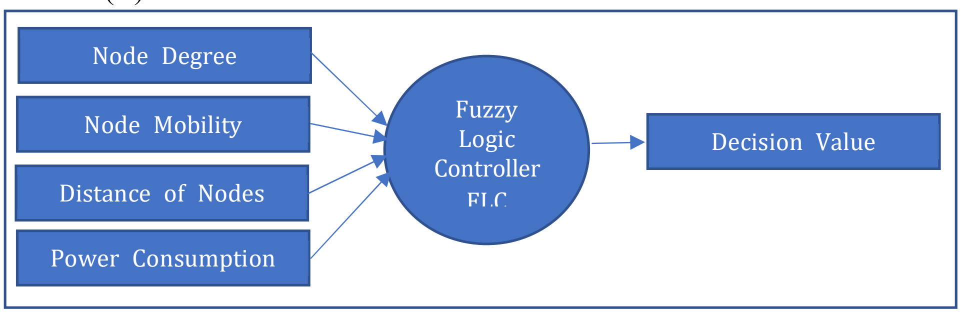


Figure 1 FBS Structure

The terms set of Input parameters are defines respectively as:
ND: {Low, Medium, High}
NM: {Low, Medium, Fast}
DN: {Near, Middle, Far}
PC: {Low, Medium, High}
The terms set of Output parameters are defines respectively as:
OP: {Remain, Suspend, Leave}

6. Fuzzy Control

Fuzzy control system describes the actions for diverse classes represented by Fuzzy sets [29]. The process consists of four steps as following:

a. **Fuzzification:** Obtaining the membership value by comparing the input variables with the membership functions.
b. **Inference Engine:** Combining the membership value to obtain the degree of fulfillment of each rule and generate the rules depending on the firing strength [30].
c. **Defuzzification:** Transforming the fuzzy output of a fuzzy inference into a crisp.

7. Fuzzy Control System

Knowledge base is the form of Fuzzy Rules. We define a set of linguistic variables that describe the input and output parameters as shown in Table 1. The rule base describes the relation between the conditions and the outputs. The algorithm is given (IF…Then) expression as shown in Figure 2.

1. If (ND is Low) and (NM is Slow) and (DN is Near) and (PC is Low) then (OP is Remain) (1)
2. If (ND is Low) and (NM is Slow) and (DN is Middle) and (PC is Low) then (OP is Remain) (1)
3. If (ND is Low) and (NM is Slow) and (DN is Far) and (PC is Low) then (OP is Remain) (1)
4. If (ND is Low) and (NM is Slow) and (DN is Near) and (PC is Low) then (OP is Remain) (1)
5. If (ND is Low) and (NM is Slow) and (DN is Middle) and (PC is Medium) then (OP is Remain) (1)
6. If (ND is Low) and (NM is Slow) and (DN is Far) and (PC is Medium) then (OP is Remain) (1)
7. If (ND is Low) and (NM is Slow) and (DN is Near) and (PC is High) then (OP is Remain) (1)
8. If (ND is Low) and (NM is Slow) and (DN is Middle) and (PC is High) then (OP is Remain) (1)
9. If (ND is Low) and (NM is Slow) and (DN is Far) and (PC is High) then (OP is Remain) (1)
10. If (ND is Low) and (NM is Medium) and (DN is Near) and (PC is Low) then (OP is Suspend) (1)

Figure 2: Sample of Rules

13. If (ND is Low) and (NM is Medium) and (DN is Near) and (PC is Medium) then (OP is Suspend) (1)
14. If (ND is Low) and (NM is Medium) and (DN is Middle) and (PC is Medium) then (OP is Suspend) (1)
15. If (ND is Low) and (NM is Medium) and (DN is Far) and (PC is Medium) then (OP is Suspend) (1)
16. If (ND is Low) and (NM is Medium) and (DN is Near) and (PC is High) then (OP is Suspend) (1)

Table 1: Clustering of the mobile nodes using Fuzzy-Based System (FBS) consideration

No	ND	NM	DN	PC	OP	41	Medium	Medium	Middle	Medium	Suspend
1	Low	Slow	Near	Low	Remain	42	Medium	Medium	Far	Medium	Suspend
2	Low	Slow	Middle	Low	Remain	43	Medium	Medium	Near	High	Suspend
3	Low	Slow	Far	Low	Remain	44	Medium	Medium	Middle	High	Suspend
4	Low	Slow	Near	Medium	Remain	45	Medium	Medium	Far	High	Suspend
5	Low	Slow	Middle	Medium	Remain	46	Medium	Fast	Near	Low	Leave
6	Low	Slow	Far	Medium	Remain	47	Medium	Fast	Middle	Low	Leave
7	Low	Slow	Near	High	Remain	48	Medium	Fast	Far	Low	Leave
8	Low	Slow	Middle	High	Remain	49	Medium	Fast	Near	Medium	Leave
9	Low	Slow	Far	High	Remain	50	Medium	Fast	Middle	Medium	Leave
10	Low	Medium	Near	Low	Suspend	51	Medium	Fast	Far	Medium	Leave

11	Low	Medium	Middle	Low	Suspend	52	Medium	Fast	Near	High	Leave
12	Low	Medium	Far	Low	Suspend	53	Medium	Fast	Middle	High	Leave
13	Low	Medium	Near	Medium	Suspend	54	Medium	Fast	Far	High	Leave
14	Low	Medium	Middle	Medium	Suspend	55	High	Slow	Near	Low	Remain
15	Low	Medium	Far	Medium	Suspend	56	High	Slow	Middle	Low	Remain
16	Low	Medium	Near	High	Suspend	57	High	Slow	Far	Low	Remain
17	Low	Medium	Middle	High	Suspend	58	High	Slow	Near	Medium	Remain
18	Low	Medium	Far	High	Suspend	59	High	Slow	Middle	Medium	Remain
19	Low	Fast	Near	Low	Leave	60	High	Slow	Far	Medium	Remain
20	Low	Fast	Middle	Low	Leave	61	High	Slow	Near	High	Remain
21	Low	Fast	Far	Low	Leave	62	High	Slow	Middle	High	Remain
22	Low	Fast	Near	Medium	Leave	63	High	Slow	Far	High	Remain
23	Low	Fast	Middle	Medium	Leave	64	High	Medium	Near	Low	Suspend
24	Low	Fast	Far	Medium	Leave	65	High	Medium	Middle	Low	Suspend
25	Low	Fast	Near	High	Leave	66	High	Medium	Far	Low	Suspend
26	Low	Fast	Middle	High	Leave	67	High	Medium	Near	Medium	Suspend

27	Low	Fast	Far	High	Leave	68	High	Medium	Middle	Medium	Suspend
28	Medium	Slow	Near	Low	Remain	69	High	Medium	Far	Medium	Suspend
29	Medium	Slow	Middle	Low	Remain	70	High	Medium	Near	High	Suspend
30	Medium	Slow	Far	Low	Remain	71	High	Medium	Middle	High	Suspend
31	Medium	Slow	Near	Medium	Remain	72	High	Medium	Far	High	Suspend
32	Medium	Slow	Middle	Medium	Remain	73	High	Fast	Near	Low	Leave
33	Medium	Slow	Far	Medium	Remain	74	High	Fast	Middle	Low	Leave
34	Medium	Slow	Near	High	Remain	75	High	Fast	Far	Low	Leave
35	Medium	Slow	Middle	High	Remain	76	High	Fast	Near	Medium	Leave
36	Medium	Slow	Far	High	Remain	77	High	Fast	Middle	Medium	Leave
37	Medium	Medium	Near	Low	Suspend	78	High	Fast	Far	Medium	Leave
38	Medium	Medium	Middle	Low	Suspend	79	High	Fast	Near	High	Leave
39	Medium	Medium	Far	Low	Suspend	80	High	Fast	Middle	High	Leave
40	Medium	Medium	Near	Medium	Suspend	81	High	Fast	Far	High	Leave

8. FUNCTIONS FOR CREATING FUZZY SETS

This way of creating fuzzy set objects [31]. Fuzzy Logic provides number of functions to create special types of fuzzy sets. There are many membership functions that built from several basic functions such as Triangular-shaped membership function where the three points (3,6,8) forming a triangle as shown in Figure 3.

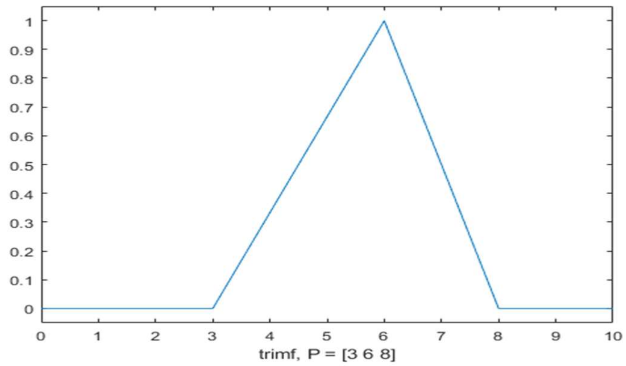


Figure 3: *Triangular-shaped membership function* curve

8. 1Triangular-shaped membership function

Asymmetric trimf is given by the following expression y = trimf(x, [a b c]), where the triangular curve is a function of a vector, x, and depends on three scalar parameters a, b, and c, as given by the following equation. The parameters a and c locate the "feet" of the triangle and the parameter b locates the peak.

$$f(x, a, b, c) = \begin{cases} 0, & x \leq a \\ \dfrac{x-a}{b-a}, & a \leq x \leq b \\ \dfrac{c-x}{c-b}, & b \leq x \leq c \\ 0, & c \leq x \end{cases}$$

$$f(x, a, b, c) = max\left(min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}, 0\right)\right)$$

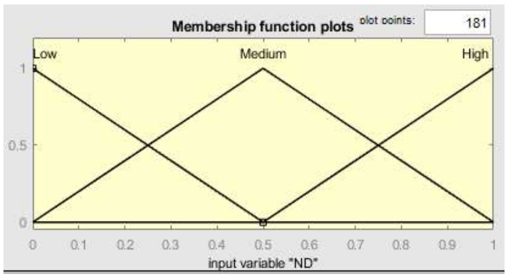
8. 2Simulation Environment

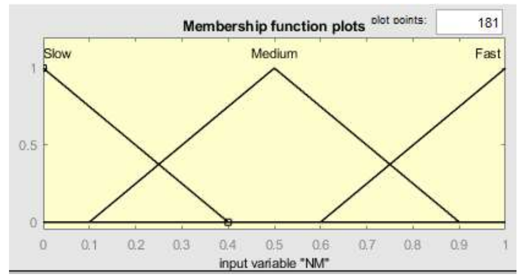
The proposed method has been carried out in MATLAB using Fuzzy Toolbox. The input parameters are listed in the adjoining Table 2. The membership function for our proposed parameters is shown in Figure 4.

Table 2 Simulation Parameters

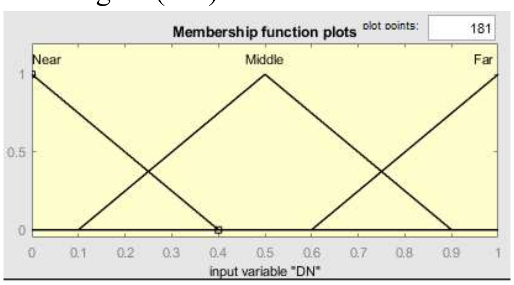
Parameter	**Value**
Simulator	MATLAB
Input Parameters	4
Output Parameters	1
AND Method	MIN
OR Method	MAX
Membership Function	trimf
Implication	MIN

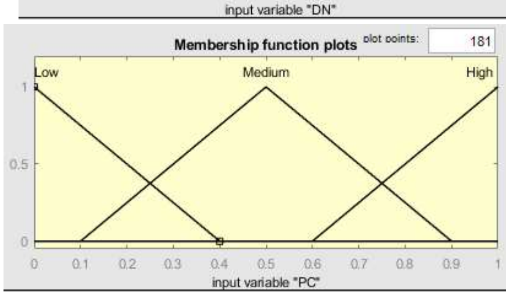
Aggregation	MAX
Defuzzification	Centroid





Node Degree (ND) Node Mobility (NM)





Distance of Nodes (DN) Power Consumption (PC)

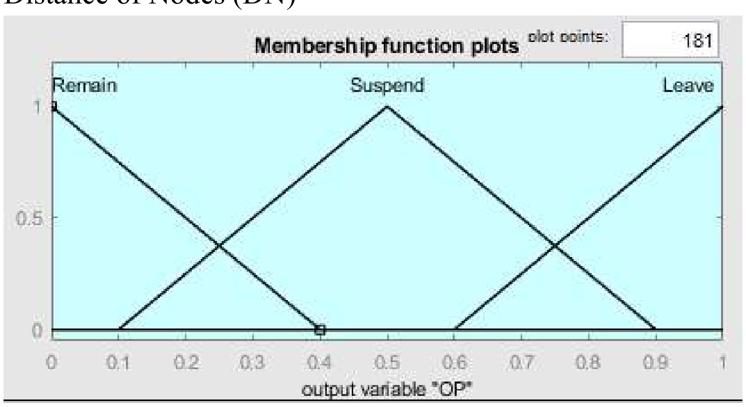


Figure 4 Membership functions of FBS

8. 3Performance Analysis

To illustrate the performance of our proposed method, we set diverse values among those parameters in order to determine the decision value. The simulation results of Node Mobility in scenario 1 as shown in Figure 5, When we set the node mobility to 0.1 which indicates that the node has the lowest mobility, and we set respectively the other nodes as node degree = 0.1, Distance of node = 0.9, and Power Consumption = 0.1, we observe that the decision value of leaving is decreased to 0.392; however, when the node has the highest mobility as 0.9 will leave even the other nodes meet the requirements. We conclude that the node mobility is the most significant parameter that has had impact the stability of the network.

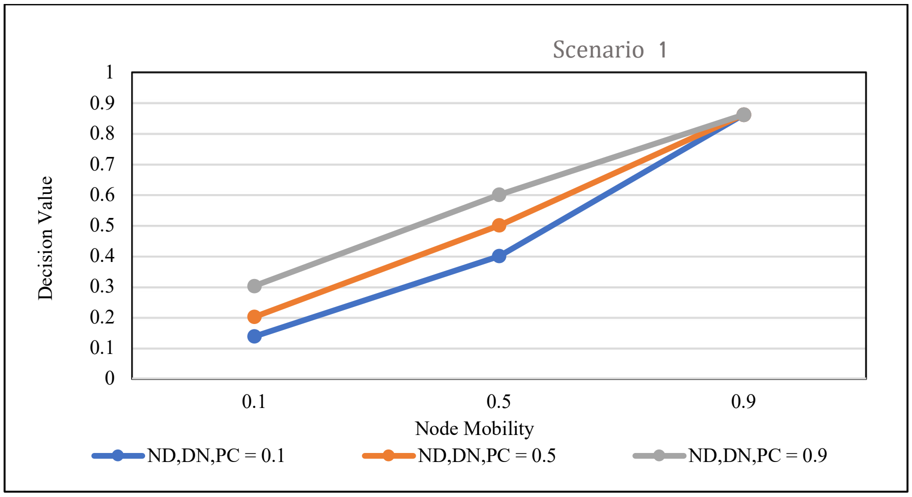


Figure 5: Node Mobility Simulation

In scenario 2 we consider Node Degree that has the lowest degree as 0.1, we observed the decision value of leaving is decreased as shown in Figure 6. However, when node mobility set to 0.9, the decision value of leaving is increased. We generalized that the node mobility parameter affects the value of Node degree parameter.

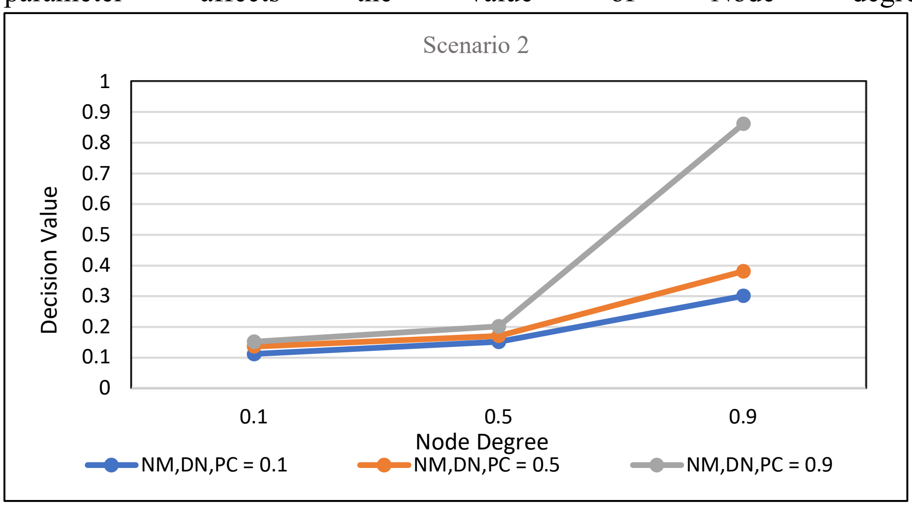


Figure 6: Node Degree Simulation

The simulation results of the Distance of Node in scenario 3 are shown in Figure 7. We set the value [0.1,.0.5,0.9], we witness that there's no impact due to the role of other parameters. We conclude that wherever the distance of nodes near or far, it doesn't impact the performance while the other nodes meet the requirements.

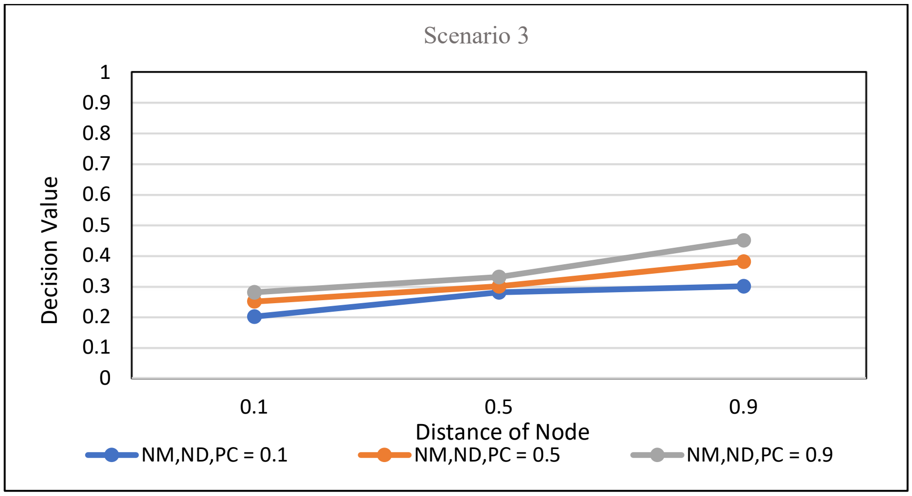


Figure 7: Distance of Node Simulation

In scenario 4 as shown in Figure 8, we set the Power Consumption as [0.1,0.5,0.9] to figure out the impact of this parameters in order to take it in our consideration. When we set the power consumption to 0.9, we observe that the possibility of leaving is decreased.

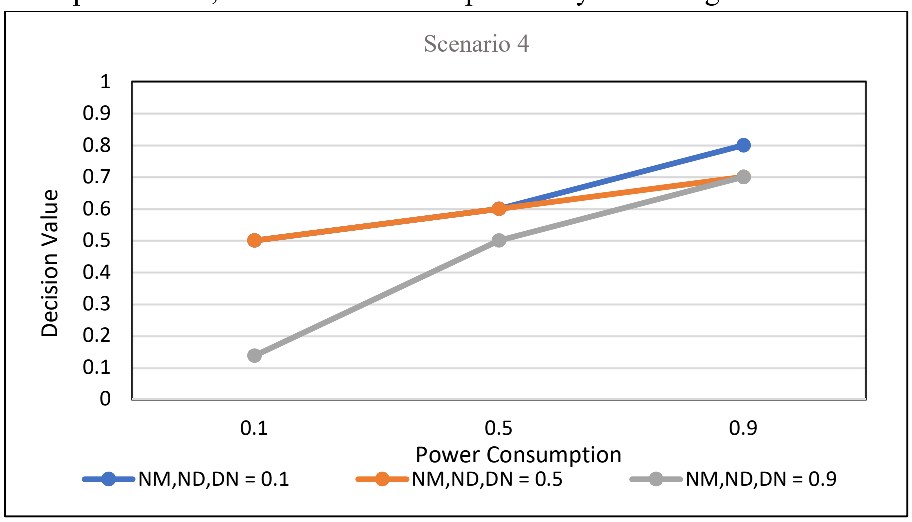


Figure 8: Power Consumption Simulation

9. Conclusion

We have made an attempt at simulation of certain highly probable operating conditions with ad hoc wireless networks and produced certain output values which reflect their overall performance in the face of threats, attacks and operating hazards. We perform our proposed architecture based on Fuzzy C means to determine whether the nodes will be elected as a cluster head or not. We had predicted that lower node speeds keep the network stable and reliable, and hence give better network performance but it has not quite always worked that way with the consideration of other parameters as well as Node Degree. The Distance of node value has been less impact compared to other simulations in related works possibly since we simplified our study with just four parameters. Quite a few of the results were found to be in keeping with predicted trends but there were a few results which could be due to conflicting or clashing effects of inputs and needed further analysis with possibly different input frameworks. There has also been a prominent statistical element in every simulation since Node Mobility had a big range and packet drops only had a probability. It is possible that very large numbers of simulations could have led to more predictable results.

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