Fuzzy Control Based Mobility Framework for Evaluating Mobility Models in MANET of Smart Devices

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ABSTRACT

The MANET is one of the most useful networks that established dynamically among all connected devices without fixed infrastructure in a decentralized approach. Smart devices such as Smart home automation entry point, smart air conditioners, Smart hubs, Smart thermostat, Color changing smart LEDs, Smart Mobiles, Smart Watches and smart Tablets etc. are ubiquitous in our daily life and becoming valuable device with the capabilities of wireless networking using different wireless protocols that are typically used with an IEEE 802.11 access point. MANETs provide connectivity in heterogeneous network with decentralized approach. MANET is formed by itself when two or more smart devices has active connection. The fuzzy logic control system is a novel approach that is utilized in various area of research because of the performance ability to control the system. The proposed research is focused mainly to design a fuzzy logic control mobility framework for evaluating mobility models in MANET of smart devices in internet of things environment. To implement this research we developed a new fuzzy control based mobility framework for communication in MANET of smart devices. Smart devices are considered as mobility nodes in MANET network system. The related work shows various mobility models to reproduction the movements of nodes but unfortunately most of them are not working in reality. The proposed mobility framework is tested on simulation environment and results perform the better evaluation of mobility models in MANET. This research may be useful in the development of internet of things framework, where smart devices are connected to each other in real time.

KEYWORDS

MANET Mobility Models, Ad Hoc Networks, Smart Devices, Fuzzy Logic, Internet of Things.

1 INTRODUCTION

Wireless networking is bringing turned progressively prominent in the computer organizations from last 50 years. Wireless computing refers to computing systems that are connected to their working environment via wireless links [24]. Now a days most organizations use wireless network that is based on cells, every cell must hold basic office that is wired should an altered wired system. These basic wired offices connect to the smart devices and provide them the wireless facility to connect each other within the cell or outside the cell network. The smart devices are becoming more and more capable day by day [15]. In the last years, smartphones, tablets and other mobile communication devices have become popular [32]. When a smart device or smart user moves from one location to a new location it has to establish a new connection with the target access point or a base station or neighborhood smart device [18]. Every smart device user is free to connect any other smart device, also they are free to move randomly [43]. Every pair of the smart device has a way with various connections among them in the area of similar communication. Because of the higher use of mobility, the communication connections among smart devices are transient and temporarily connected [35]. It is expected that by 2020, the development of internet of smart devices connected together exponentially with 50 billion smart devices [44]. This development will not depend on mankind's population but the reality that units we utilize consistently. The reality of interconnectedness things are cooperating man to machines and machine to another machine. They will be talking with each other. The definition of internet of things can be described as "a pervasive and ubiquitous system which empowers screening furthermore control of the physical earth by collecting, processing, also analyzing those information created eventually sensors". In the article [10], a unified architecture mobility model for context information distributions in ubiquitous computing is presented. In this model researcher presents the solution and comparing a large number of another solutions and based on the observations they find various research challenges still unsolved. The Wireless sensors network is a part of MANET, in this network, all mobility nodes are connected to neighborhood nodes, each node is operated by the battery including low energy, computations also wireless transceiver [40]. In an article [19], researcher presents the electrical power grid that really contributed great in our daily life as well as industries. Currently, the minimization of whole energy consumption of the ad hoc networks is equal to the minimization of average energy consumption of all network devices [48]. Every node that is equipped with antenna, can be controlled its transmission energy [17]. The Fuzzy logic provides the logical reasoning that are approximate rather than exact [49]. In this article [14], researchers propose a new approach to handle the data transfer management by applying the fuzzy logic concept to a heterogeneous environment. This evolutionary paradigm enables its users to deploy a connection to a network of computing resources in an effortless fashion, where users can rabidly scale up or down their demands with trivial interaction from service provider. The ad hoc network provide the facility to connect in heterogeneous environment without centralized approach. It is created automatically when two or more device has active connection. An important issue for MANETs is mobility [26]. MANET provides connection at any area and no time bound among smart devices, if that area does not have the facility of cellular network. Generally it is used in military rescue operations or the disasters area. MANET provides the best performance in that situations where we do not want centralized storage of the information for example meeting room. Some private talk need security or privacy, at that situation MANET help us to create a virtual network without centralized server, it is one of various scenarios where MANETs perform excellent. The MANET has a self-organizing decentralized approach that form the virtual communication as shown in Figure 1.

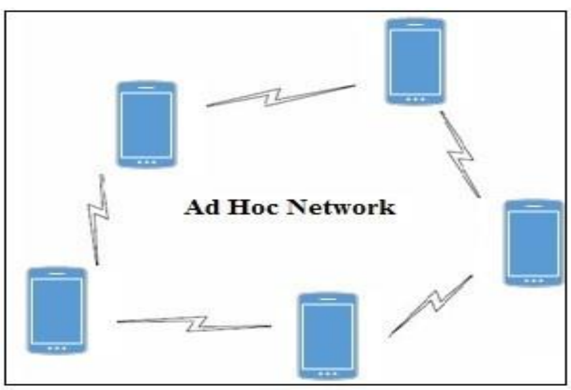

Figure 1. Ad Hoc Network of Smart Devices

The probabilistic distributions of the life of separate connections of smart devices in a vehicular ad hoc network follow the combination of various assumptions in the realistic transmissions of mobility devices [50]. Various preexisting mobility models change generally over the reality, they start with totally simulated and extremely measurable practically. The review process of individual's mobility modeling help us to know the utilization of various mobility models in MANET. The Ad Hoc means just for this reason, it is a Latin expression for an autonomous collection of mobile nodes, with networks built on the fly for a specific purpose (i.e., emergency situations, rescue operations, battlefield situations, etc.), that talk to each other over bandwidth constrained wireless links [28]. The proliferation of wireless portable devices as part of everyday life, such as PDA, mobile phones, and laptops etc. is progressing to add the facility of MANET inside the device for sharing the data among smart devices. However, communication over existing infrastructures may be precluded due to deficient facilities, or impractical in terms of time, expense and power. The mobile ad hoc network is the network of autonomous smart devices where every smart device acts as a source, a destination, as well as an intermediate router [9]. MANET contains an extraordinary sub form that claiming remote network without server for transferring information from one smart device to another. Actually wireless network requires the basic fixed offices that are answerable to receive and sending the information among smart mobility devices but ad hoc network do not require this kind of fixed office (see figure 2).

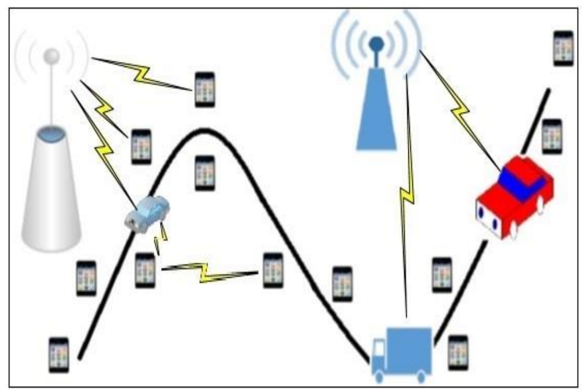
Figure 2. Controlling the movement of Nodes using wireless access point

Now-a-days, in whole world the smart devices are increasing exponentially because operating systems used in smart devices provide most user friendly platform [1]. The smart devices mobility causes incessant and flighty transforms the discretionary system topology for transforming the information. The Messages requiring a destination outside this local neighborhood zone must be hopped or transformed through the nearest smart device that is working like a router in the ad hoc network [4]. All neighbors of one devices are ranked by their trust value [47]. The growth of internet of things initially started from 2008 by connecting the physical objects to the internet. The physical objects are connected with smart database that have collection of smart data. The framework has image recognition technology for identifying the physical object, buildings, peoples, logo, location etc. for business and customers. Now internet of things (IOT) is shifting from information based technology to operational based technology ie. IPV4 (man 2 machine) to IPV6 (machine 2 machine). It combines sensors, smart devices and interfaces like Smart Grid. Figure 3 represents the number of connected smart devices worldwide from 2012 and 2020.

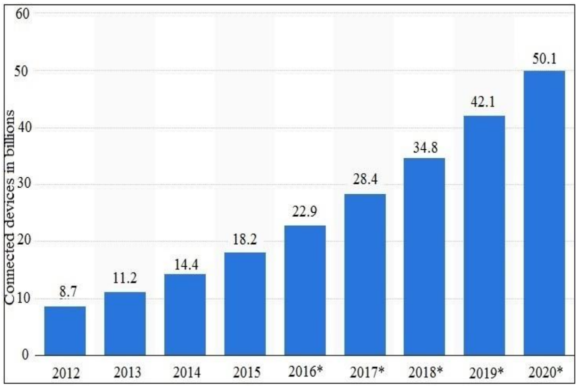

Figure 3. Smart Devices yearly basis in millions [44]

In 2012, the number of connected devices worldwide reached 8.7 billion [44]. In the article [42], the researcher presents an architecture for removing the barriers among network nodes to allow these devices seamlessly as well as personally. The architecture has three kind of services- the node discover service, the mobility sessions and profile mobility. In the article [13], service discovery has been done in a peer-to-peer mode rather than a centralized mode. In the paper [3], the researcher present a very beautiful technique to identify the traffic at routes and provide feasible decisions to the traffic system, which makes the decision support intelligent by using the wireless sensor technologies. Ad hoc network of smart devices provide facility to send messages from one smart device to another without using intermediate devices inside the entire network graph [2]. MANET does not have any controlling office for communication. Every device itself in MANET acts as a router for forwarding and receiving packets to/from other devices [37]. In the article [33], authors are proposed the use of fuzzy logic to perform role assignment during route establishment and maintenance. For providing the best performance of smart devices network and avoiding the collisions problems using the proposed research is the main goal of our study. One of the most important routing technique proposed in the article [38] is cluster based routing in Mobile Ad Hoc Networks. It is considered one of the convenient method of routing to discover the smart devices in the range of MANET. According to recent research on the message passing in ad hoc network, there are using basically two techniques- one of them is deterministic and other is Probabilistic technique. The first technique is used to build a network backbone for covering all the devices in the entire network. Other technique is used to rebuild the backbone for every devices and select the device probably and then send the message. The probability approach may very useful to find best route [51] for sending data among smart devices by using fuzzy control system [27]. Fuzzy controllers, designed using fuzzy rules that are basic operations for fuzzy sets [25]. The proposed research applied the fuzzy framework to find optimal Mobility Models in MANET of Smart Devices. In the article [52], researchers proposed a mobility mechanism to maintain the connection among all smart devices using fuzzy logic in order to help sensor mobile nodes for controlling handoffs with the need of performance evaluation guarantee. The study presented in the article [39] is introduced a new procedure for fuzzy rule evolutions to forms an expert system knowledge.

2 RELATED WORK

The movements, positions, and acceleration also velocity of smart device users are changing time by time. The purpose of MANET is to define the movements and analyze their purpose over the time. So MANETs play the vital role to perform simulations of movements in the area of wireless network. It can be very helpful for researchers in the area of mobility modeling. The vehicular ad hoc networks are likely to be the first real large-scale deployment of a mobile ad hoc network [8]. RWP mobility models are frequently used mobility model that is widely spreading useful in the area of Mobile Ad hoc Network. Presently researchers start focusing on the alternatives of the mobility models with advanced properties. Because the mobility models more focuses on the neighborhoods smart devices for creating the connections among smart devices so sometimes it takes time to spread information among the smart devices within the range of ad hoc network. Every mobility management's device in ad hoc network is embedded and every device knows the position of all devices within the network and can communicate to each other [22]. Routing becomes more challenging when considering mobile relays [34]. In the paper [20], researchers designed a fuzzy-based priority scheduler to determine the priority of the packets with the multicast routing protocols. Many researchers proposed various types of mobility models for capturing different kinds of properties in a real time. The evaluations of mobility models are performed in mobile ad hoc networks in [11], each experiment of simulation done followed by various modeling conditions that effect realistic of the real systems.

In Random walk mobility model, every smart device can move within the range of ad hoc network from one position to another position using the random directions as well as random velocity and speed. But the movement has been performed within the fixed timing and distance traveled. After that the currently directions will be selected. In RWP mobility model, assuming that total number of smart devices within the area of rectangle that should be constant area [12]. All smart devices can move randomly from one position to another position using randomly chosen way within the minimum also maximum velocity interval. When the smart device will arrive to its destinations then this device will choose the new speed and destination, after that this process will continue until it reaches to the final destination. In the research article [36], researchers solved the distributed optimization problems in which every mobility device minimizing the overheads incurred it selves based on the mobility models as well as path finding algorithm. They develop the simulation modeling results to show the realistic behaviors of nodes [36]. In Random Direction Mobility Model, all smart devices user can be travelled in simulation range with fixed speed and directions. After that the device stop then it discover the latest directions and speed using the random selection. This process will repeat randomly. Figure 4 represents the random way point mobility model movements of the smart devices.

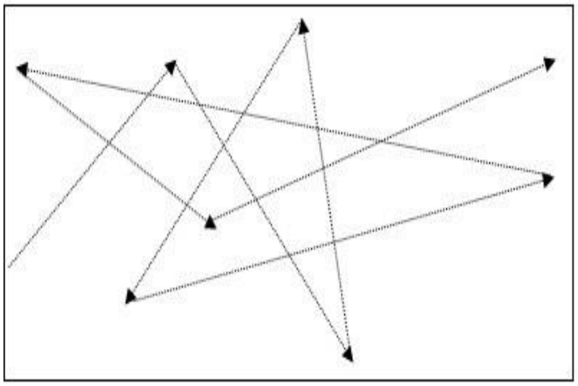

Figure 4. The movement of one node with an RWP mobility model

In Probabilistic Random Walk Mobility Model, the movements of smart device users using the probabilistic find directions from one location to another location. Figure 5 represents the random direction mobility movements.

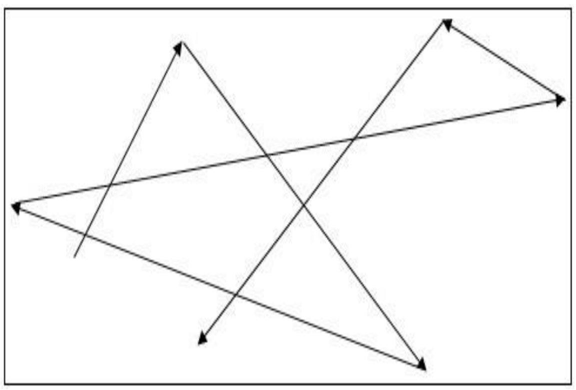

Figure 5. In RDM mobility model movements of a node

The Random Gauss Markov Model is the improved model that allow the smart devices to move randomly using random walk mobility to the fluid flow. The Column Mobility Model is used to move the devices using column line. It is very useful for discovering the device within the simulation area. Various researchers modify the column mobility model that allowed smart devices to discover neighborhood devices using a line. The smart devices are shifted to the refer location inside the refer grid after shifted the smart device then allow it for moving in a random refer location. In the Generalized Trace Based Mobility Model, the smart devices users are connected in MANET. It is an emerging technology that allowed the access point for connection creation process among the smart devices. Figure 6 is representing the basic model of mobility communication among smart devices.

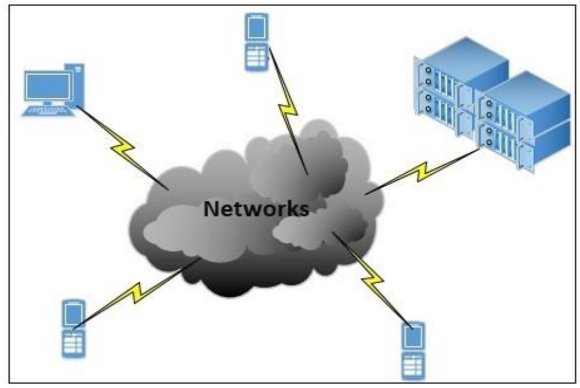

Figure 6. Basic model for mobile communications

The smart device users mobility in MANET determine the route of movement is the challenges and difficult for predicting movement of smart devices. The smart devices typically contain a large amount of sensitive personal and corporate data and are often used in online payments and other sensitive transactions [5]. In the article [6] authors presents the simulation analysis that shows the significant improvements in the performance evaluations of route discovery [23]. The real tracing of smart users in mobility environment is the real movement in geographic simulated area. Sometimes these tracing perform accurate and result produced like real tracing. Every device needs to update its address in the ad hoc network database only when leaving the area [46]. Various mobility models trace the movement of devices and collect the result for evaluating the performance. The smart devices on the boundary of the routing area are called peripheral devices and play an important role in the reactive zone-based routing discovery [45]. The boundless simulation area mobility model generate the torus shaped simulated area that allow smart users to move from one location to another in a boundless simulation area. This coverage area will folded in x-axis as well as y-axis and generate a cylinder. The figure 7 represents the closed coverage rectangular area mapping with torus [12].

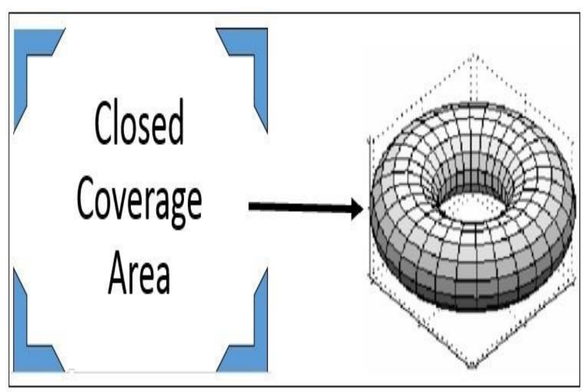

Figure 7. Closed coverage rectangular area mapping with torus

The graph based mobility model moves the smart device in the edge of the graph in the network and visit all the vertices among the graph. The smart device users choose the vertex randomly in a graph and perform the evaluation in the simulation area of the ad hoc network [12]. For the mobility generation a wide variety of well understood random mobility models is combined with a graph based zone model, where each zone has its own mobility model [21]. The keys management scheme is one of the most important technique for securing the data among the devices of ad hoc network system, it is based on key pre distributions technique for ad hoc network to solve the key management problems in authorities-based MANET. The Keys management's scheme is designed for self-organizational or authorities-based ad hoc networks [30].

3 APPLYING FUZZY CONTROL SYSTEM IN MOBILITY MODEL

The fuzzy logic control system is a novel approach that is utilized in various area of research because of the performance ability to control the system. The approach presented in [41] has been successfully applied to fuzzy models of real world systems. The fuzzy control system is the enhanced system from fuzzy logic theory (figure 8, 9).

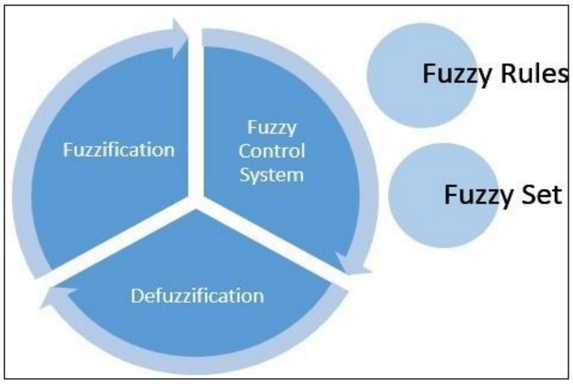

Figure 8. Fuzzy control System

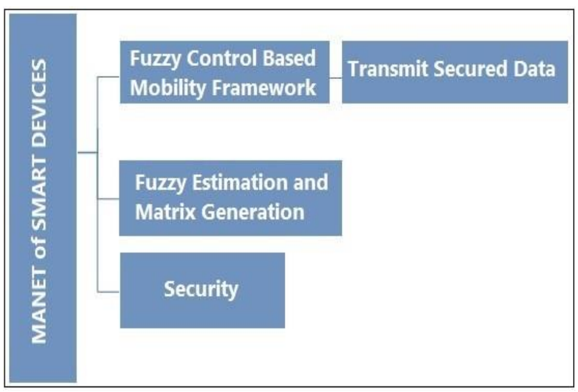

Figure 9. Fuzzy mobility framework

The Fuzzification technique is used to change input variables like ERROR and Change in ERROR. This technique is based on the linguistic rules rather than the empirical model.

1) Fuzzy logic control system can work with negative (High, Medium Low) inputs.
2) It can work with low speed processor.
3) It can work with less storage device.

The fuzzy rules engine is consisted of a set of linguistic statements [16]. Fuzzy rules are in the form E(X), CE(Y) O (Z). Suppose error is X, changes in error is Y then output will be Z. so fuzzy rules are the combination of fuzzy propositions. We consider fuzzy error symbols in Table 1 for consideration in Fuzzification.

Table 1. Fuzzy Symbols

Symbol	**Description**
E	Error
CE	Changes in Error
NegH	Negatives Highest
NegM	Negatives Medium
NegL	Negatives Lower
N	NULL
PosH	Positives Highest
PosM	Positives Medium
PosL	Positives Lower

The Table. 2 represents the linguistics variables with fuzzy rules.

Table 2. Rule Base Table with 49 Rules.

E/CE	**NegH**	**NegM**	**NegL**	**N**	**PosH**	**PosM**	**PosL**
NegH	NegB	NegB	NegB	NegB	NegM	NegL	N
NegM	NegB	NegB	NegB	NegM	NegL	N	PosH
NegL	NegB	NegB	NegM	NegL	N	PosH	PosM
N	NegB	NegM	NegL	N	PosH	PosM	PosL
PosH	NegM	NegL	N	PosH	PosM	PosL	PosL
PosM	NegL	N	PosH	PosM	PosL	PosL	PosL
PosL	N	PosH	PosM	PosL	PosL	PosL	PosL

The Memberships service is one of the service that serves as essentials buildings block in a varieties of other services and applications in ad hoc networks of smart devices (figure 10).

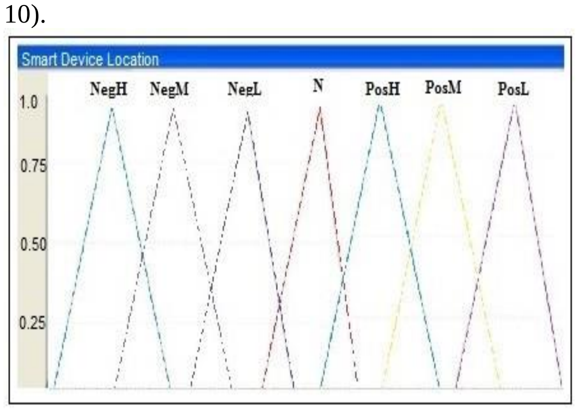

Figure 10. Smart device location

This service is used to provide service to every device with a view regarding another device inside the ad hoc network [7]. The Memberships functions could be with different shapes [31] (table 3).

Table 3. Smart Device Location Error/ Change in Error

When smart devices will connect in ad hoc network then fuzzy rules will applied. If devices have connection error (NegH) and changes in error is NegH then the output is NegH so the connection is aborted in the comparison of Connection establishment. When we find error or changes in error then fuzzy control system will handle the input. The fuzzy system will reduce the connection error to null (zero) by using changing in altitude (figure 11).

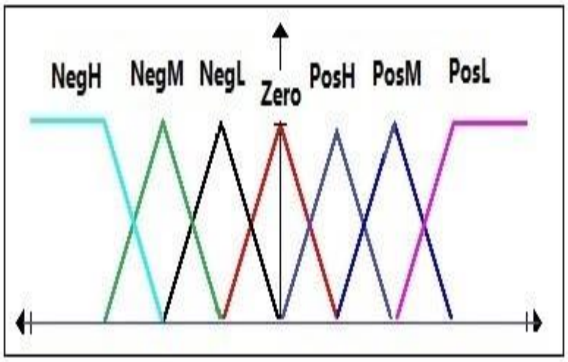

Figure 11. Fuzzy system for smart moving device

Table 4 represents the output function that is composed of seven fuzzy functions.

Table 4. Output functions

Output	Error/ Change in Error
Smart Device Location	NegH, NegM, NegL,N, PosH, PosM, PosL

4. FUZZY CONTROL BASED MOBILITY FRAMEWORK

The proposed framework is a collection of fuzzy random waypoint mobility model, fuzzy estimation and matrix generation and security. We can discover smart devices within entire network and transmit secured data among them.

The procedure to find new position of the smart device is as follows

1. Get the position (X_1, Y_1) of smart device in ad hoc network.
2. Get current Speed (s) of smart moving device in ad hoc network.

The basic formula to get speed is as following.

Speed (s)= distance (d)/time (t).

3. If time=t and angle is ɵ (positive) then we consider the new location of smart device as follows.

$X_2 = X_1 + s * t * \cos(ɵ);$

$Y_2 = Y_1 + s * t * \sin(ɵ);$

If ɵ is negative then

$X_2 = X_1 - s * t * \cos(ɵ);$

$Y_2 = Y_1 - s * t * \sin(ɵ);$

The figure 12 shows that.

4. Find the real Location of smart device.

Location L= get_New_Location(new point(smart device);

Input	Error/ Change in Error
Smart Device Location	NegH, NegM, NegL,N, PosH, PosM, PosL

Example: L=(x_1, y_1)

5. Find theoretical location

Location ref= get_Reference_Location(new point(smart device);

Example: ref=(x_2, y_2)

6. Find distance between L and ref.

Distance (d)=sqrt($((x_2-x_1)^2 - (y_2-y_1)^2)$)

7. Find random location (X, Y) of smart device at the diagonal of triangle.

X=Math.random(d.getX());

Y=Math.random(d.getY());

8. Find the actual location of smart device according to the diagonal of triangle.

May be the device is up or down from diagonal.

If device is upper than the diagonal then increase the value of X and Y as follows.

X=X+ξX;

Y=Y+ξY;

Otherwise

X=X-ξX;

Y=Y-ξY;

9. Return new Location(X, Y)

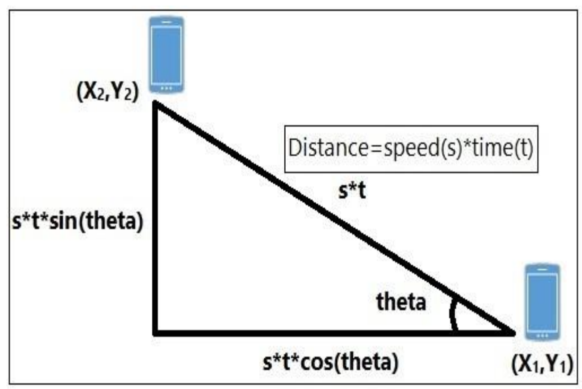

Figure 12. New Smart device location

By above observation, we can get the new position of the smart device even it is on the diagonal or upper than the diagonal or lower than the diagonal. Now we apply fuzzy rules to find the actual location. Now we will make the level of output like high, medium or low speed, we can say these level as a membership function of the fuzzy logic. The figure 13 represents the speed of the smart moving device.

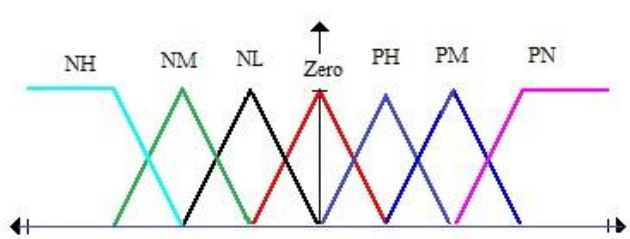

Figure 13: speed of the smart moving device

Now we want to find angle ɵ between base and diagonal. The figure 14 represent the fuzzy graph between maximum angle and minimum angle.

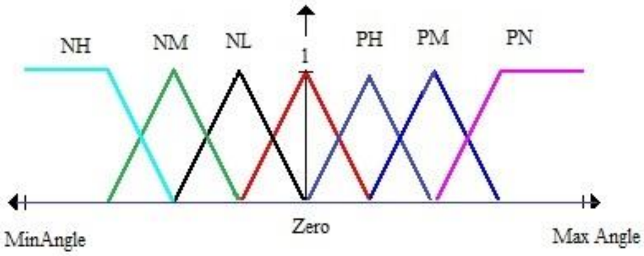

Figure 14: fuzzy graph between maximum angle and minimum angle

Now we will find velocity using speed and angle. The figure 15 represents the fuzzy graph between max angular-velocity and min angular-velocity.

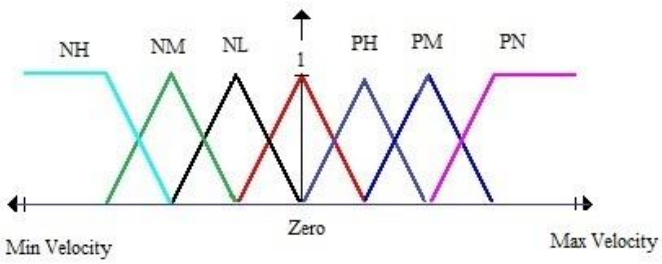

Figure 15: fuzzy graph between max angular-velocity and min angular-velocity

The following table 5 represents the velocity using speed and angle.

Table 5. Fuzzy rules for speed and angle

Speed	Angle (ɵ)						
	Neg H	Neg M	Neg L	Zero	Pos H	Pos M	Pos L
Neg H	N/A	N/A	N/A	Neg H	N/A	N/A	N/A
Neg M	N/A	N/A	N/A	Neg M	N/A	N/A	N/A
Neg L	N/A	N/A	N/A	Neg L	N/A	N/A	N/A
Zero	Neg H	Neg M	Neg L	Zero	Pos H	Pos M	Pos L
Pos H	N/A	N/A	Zero	PosL	N/A	N/A	N/A
Pos M	N/A	N/A	Zero	PosL	N/A	N/A	N/A
PosL	N/A	N/A	Zero	N/A	N/A	N/A	N/A

Apply the fuzzy rule if ɵ=0, velocity=0 then speed=0. But original quality has standard that will be situated zero should a degree from claiming ɵ=0.8 and velocity= 0.4. This will be AND rule. In this rule the least paradigm may be utilized and the fuzzy set zero for speed may be reduced at 0. 4 upon that range. Figure 16 is representing the angle, velocity and speed.

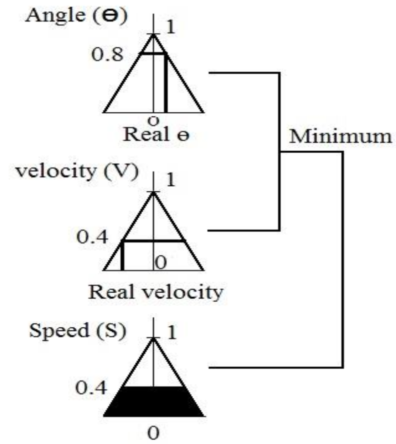

Figure 16: speed using angle and velocity

Using fuzzy rules, the figure 17 represents the negative low, positive low and zero rule. It show the outcomes "assuming that ɵ =0, v=NL then s will be NL" also "assuming that ɵ =PL, v=0 then s will be 0".

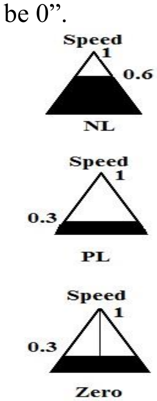

Figure 17: Speed on Negative Low, Positive Low and Zero

Figure 18 shows that the effect of overlapping, it can be decreased.

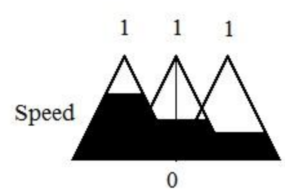

Figure 18: Effect of Overlapping

The figure 19 shows the final mobility speed using the fuzzy control system. The result show the speed after applying defuzzyfication center of gravity procedure.

Figure 19: Final Speed using center of gravity rule

We set the simulation parameters to find the performance evaluation using MATLAB code. Table 6 represents the simulation parameters within the range of 250 meters.

TABLE 6. Simulations Parameter values

Simulations Parameters	**Values**
Simulators	MATLAB
Number of Mobile Nodes	20
Networks coverage	1000x1000 sq m
Transmissions	250 meters
Packets rates	4 packets/sec
Simulation Time	500s
Packets width	64 Bytes

Figure 20, 21, 22 and 23 represents the movement of 20 smart devices in 3 dimensional area of 20X20 meters, we find these results at 7.5, 157.9, 257.3 and 500 seconds.

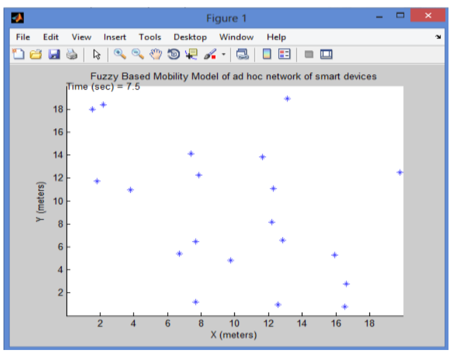

Figure 20: smart devices movement at 7.5 sec time

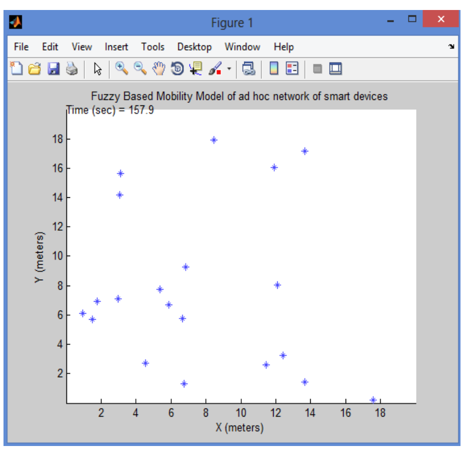

Figure 21: smart devices movement at 157.9 sec time

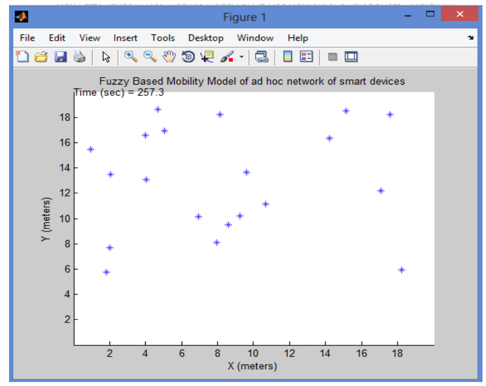

Figure 22: smart devices movement at 257.3 sec time

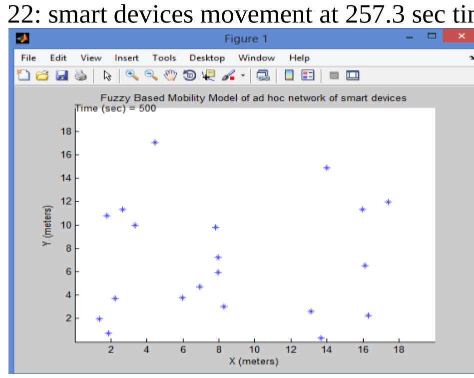

Figure 23: smart devices movement at 500 sec time

For performance evaluation of mobility models using fuzzy control based framework, we consider four mobility models (1. Fuzzy based mobility, 2. Random way point, 3. Column mobility, 4. Graph based mobility). We choose three areas- small (500m*500m), medium (750m*750m) and large (1000m*1000m) with varying the smart devices as 20, 50 and 100. The comparisons are measured by the delivered packets measurement (DPM), average delay measurement (ADM) and routing load measurement (RLM). The DPM is calculated by dividing the delivered data packets (ddp) by total number of packets (tnp). We can derive the formula to calculate DPM as DPM=ddp/tnp. The ADM is defined as the time taking by the packets to move from sender to the receiver nodes. The RLM is defined as the load of authenticated packets on the network divided by the total number of packets. The comparison study in figure 23, 24 and 25 of three mobility models (RWPMM, CMM, GBMM) with proposed fuzzy control based mobility model (FCBMM) is illustrated based on DPM, ADM and RLM. The results shows the better performance evaluation of mobility models in MANET of smart devices.

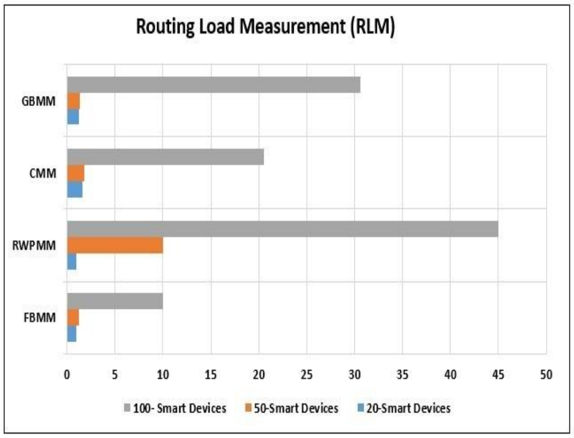

Figure 24: routing load measurement

* FBMM- Fuzzy based mobility model
RWPM-Random waypoint mobility model
CMM- Column mobility model
GBMM- Graph based mobility model

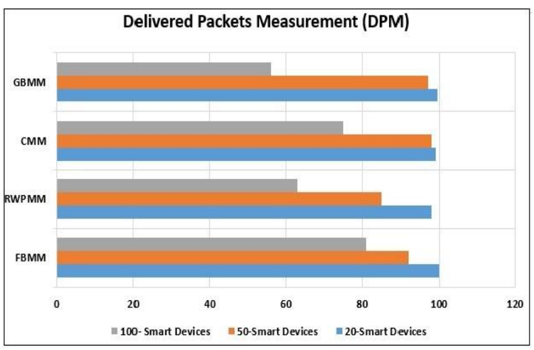

Figure 25: Delivered packets measurement

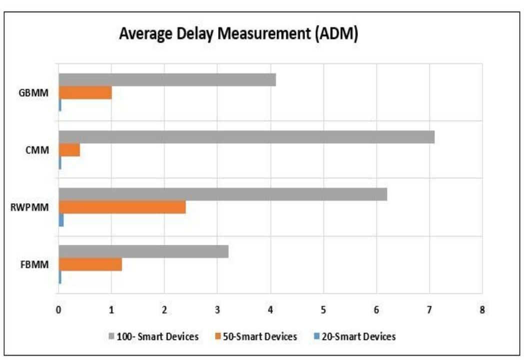

Figure 26: Average delay measurement

5 CONCLUSION

The MANETs are self-organizing decentralized without fixed infrastructure network of wireless smart gadgets that provide facility to send and receive messages among wireless smart devices within its transmission range. The information passing requires a destination outside this local neighborhood zone must be hopped or transferred through the nearest device to the appropriate target address. As a consequence of node mobility fixed source/destination paths cannot be maintained for the lifetime of the network. In this article we perform the evaluation of mobility modeling using fuzzy logic control system. Based on the smart device location, we analyze the fuzzy logic and check the probability of connection, generated based on fuzzy control system. The fuzzy control system framework generates the realistic data for communication in mobile ad hoc network of smart devices. The proposed system is tested and results are generated using twenty smart devices. We get high throughput with more efficient values using proposed mobility model.

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