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DEVELOPMENT OF AN INTELLIGENT MANET SYSTEM MODEL FOR DETECTION AND PREVENTION OF ANNOMALY USING ANFIS

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ABSTRACT

MANET (Mobile Ad-Hoc Network) is a self-configured network of nodes connected through wireless links, in an arbitrary topology. Each node is an independent node, which can play a role of host, router & receiver. The connectivity is established by operating system hosted on participating nodes. Routing algorithm establishes routes and forwarding information as packets to and from source to sink station. Many routing techniques attempt to achieve optimal performance, however modifications are still required in existing routing protocols to improve the performance of MANET. An efficient MANET leads to fulfillment of three key performance metrics:

- *Maximizing PDR (Packet Delivery Ratio)*
- *Minimizing AE2ED (Average End 2 End Delay)*
- *Minimizing routing overhead (Overhead).*

There exist some predominant anomalies in Mobile Ad-hoc Network in terms of above performance metrics. Anomalies in MANET arise due to various environmental factors like variation in number of connections among participating nodes, mobility of nodes, pause time of node, rate of data packet forwarded by nodes and total density of nodes, adversely affecting its performance. In order to overcome some predominant anomalies, in this research a systematic approach has been used to develop an intelligent system model, which controls the performance adaptively.

Key words: MANET, PDR, AE2ED, Overhead

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1. INTRODUCTION

Many researchers have discussed the issues of security in MANET such as S. Umamaheswari [2] emphasized on data communication mechanism between mobile nodes based on ACO approach, V. Venkata et. al. [1] proposed a model to replicate the properties of the resistant system. However a systematic method has not been attempted earlier to develop an intelligent model for MANET to control the performance under different environmental factors. A lot of monitoring techniques are addressed in many research works for observing the accessing frequency of exchanged packets to adjust the replication factor [2]. For observing node density [6-7], detection of highly connected or powerful nodes at sparsely inhabited places is required. [4]

Unlike to a centralized approach (client/server architecture), where a client/server processes handle the monitoring of the packets and the results, There is a lack of centralized architecture in MANET, so it must handle with the challenges that the nodes and mobility are distributed over the entire network, while no dedicated module is responsible to capture the information. In MANET, the collected information for distributing the generated results among the nodes for the analysis of the unstable behavior of nodes, and the whole MANET system which constitutes another challenge [9-16]. However, these approaches are not useful to dynamic MANET, because variation in the mobility of nodes, varying number of active/in-active connections, variable pause time, variable data rate and frequently leaving or joining the network, results as highly dynamic network medium. A memory management scheme [17] was introduced to tackle queues in MANET for fixed and mobile nodes. They are also unable to reduce the overall processing overhead with proposed scheme.[18] The idea of reliability factor to determine reliable routes among the transitional nodes was introduced [19]. It was proposed a stateless approach to MANET especially when dealing with highly dynamic network. The approach was incapable to address the impact analysis process of the different parameters which determine the efficiency and overhead. [20]

A model for node mobility [21-22] was developed for modeling technique for performance analysis of MANET. They emphasized on fluid-flow based differential equation models performed for queuing analysis. They emphasized on modeling of queuing system. MANET can be modeled as a framework of Total System Intervention (TSI) and, can be shown how TSI helps after integration with model to understand the risks and opportunities. [23]

The system engineering & architecting [23] states that any problem statement in MANET may be defined more precisely and accurately. Complex systems can be developed using principles of system engineering & architecting. In network communication research, an increasing interest in designing the model for autonomic computing such as MANET [24]. Traditional methods would only focus on the reliability and robustness in the outcomes. The work may be extended to more variety of outcomes such as versatility, flexibility, resolvability and interoperability [25]. The fuzzy controllers [25] introduced for multi-routing algorithm in MANET, so that the reconstructions of path in MANET may be reduced. Although, the controllers can be designed based on two methods [26-27]. One is the feedback controller, which is suitable only for low performance communication networks. Another controller may be designed using fuzzy logic [25] for tuning the system's parameters based on the state of the system. The state of the MANET may comprise of one or more input parameters and one or more output parameters. The controller controls the output parameters of the system. Fuzzy controllers have the deficiency of having the fixed fuzzy rules and can be used only in the static environment.

2. ANOMALIES IN MANET

Anomalies are the abnormal behavior of the network. In MANET, this abnormal behavior is defined as abnormality in performance parameters (i.e PDR, AE2ED & Overhead) in heterogeneous communication environment with respect to varying network size, network connectivity, traffic pattern, mobility speed of nodes & pause time during mobility etc. There are several anomalies existed in MANET as per earlier research works. Anomalies are the abnormal behavior of the network. In MANET, this abnormal behavior is defined as abnormality in performance parameters (i.e PDR, AE2ED & Overhead) in heterogeneous communication environment with respect to varying network size, network connectivity, traffic pattern, mobility speed of nodes & pause time during mobility etc. There are mainly two types of anomalies in MANET: operational anomalies related to security, routing etc. & servicing anomalies related to the behavior of network. In this thesis, servicing anomalies are addressed. There is a need to develop a system model for capturing the behavior of Mobile Ad-hoc Network (MANET) with a view to monitor and control the anomalies that exist in MANET.

2.1. Problem Statement and Methodology

The objective of this thesis is to identify and possibly resolve the key issues in MANET which necessitates to develop an intelligent state variable model. The model controls the performance evaluation metrics. The development methodology of the model for controlling the MANET's behavior, comprises of state input-output variables. The proposed model for MANET is system is treated as a MIMO (Multi input Multi output) system. The block diagram of model formulation for MANET system is shown in figure 2 and the flow diagram of the model development is shown in figure 1.

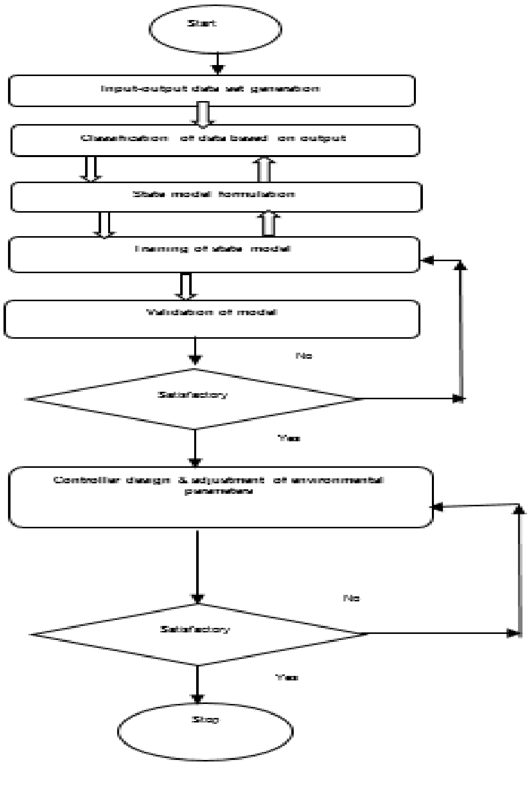

Figure 1 Steps of model development

3. STATE SPACE CONTROLLER

Analysis of State space is considered with three types of variables (input variables, output variables and state variables) that may be involved in the dynamic system modeling. The system should involve elements that memorize the values of the input for $t>=t_1$. Since integration in a continuous time control system serves as memory device, the outputs of such integrators can be treated as variables that define the internal state of the dynamic system. Thus, integrator's output serve as state variables. Dynamics of the system are specified by state variables, which are similar to number of integrators involved in the system. [25-26]. Assuming that a multi-input and multi-output system involves in integrators. Assuming also that there are p inputs $u_1(t)$, $u_2(t)$, $u_3(t)$,…… $u_p(t)$ and q outputs $y_1(t)$,$y_2(t)$,…..$y_q(t)$ define the n state variable integrator's outputs; $x_1(t)$,$x_2(2)$………$x_n(t)$ then the system is depicted by, For i=1, 2, 3……n Thus system's outputs y_1 (t), y2 (t)…$y_q(t)$, may be given by,

$$y_j(t) = g_j(x_1, x_2,, x_n ; u_1(t), u_2(t), u_3(t)\ldots u_p(t))\ldots(4.2)$$

$$\dot{x}_i(t) = f_i(x_1, x_2, \ldots, x_n ; u_1(t), u_2(t), u_3(t), \ldots u_p(t))\ldots\ldots(4.1)$$

The equation (4.1) and (4.2) becomes as:

$$\dot{x}(t) = f(x,u,t)\ldots\ldots\ldots(4.3) \qquad y(t) = g(x,u,t)\ldots\ldots\ldots(4.4)$$

The flow of equations (4.3) & (4.4) is shown in figure 2, let t=k+1, and t_0=k .

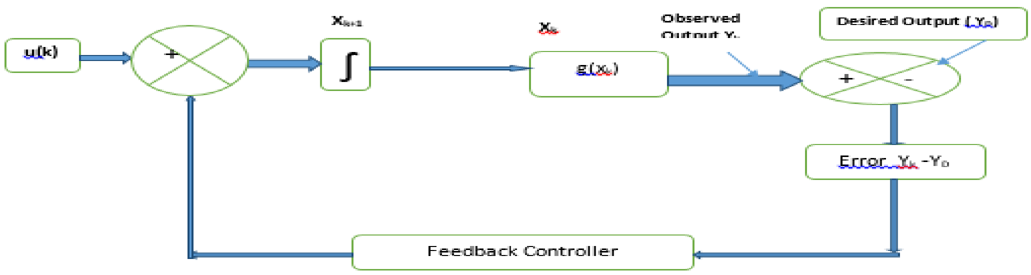

Figure 2 Block diagram representation of state space

In the diagram, the function **g** is determined using ANFIS. This relates observed output Y_k with the state variables X_k. Each output is distributed into three clusters. If the output of MANET does not lie in the desired cluster then the fuzzy controller rules are designed using ANFIS. The system controller can be designed using the ANFIS scheme. The basic structure of the ANFIS coordination controller developed to control the output of the MANET system model. The controller is shown in Fig. 2. Inputs to the ANFIS controller (i.e., error and the change in error) are modeled using Equations. 4.5 and 4.6 , as follows:

$$e(k) = Y(k) - Y_D(k) \qquad \ldots\ldots\ldots \quad (4.5)$$

$$\Delta e(k) = e(k) - e(k-1) \quad \ldots\ldots\ldots \quad (4.6)$$

Where k represents number of clusters, Y(k) is the observed output, $Y_D(k)$ is the actual output, e(k) is the error and Δe(k) is the change in error. The fuzzification module provides linguistic variables, which are inputs to the rule-based structure. The set of 243 rules have been generated based on previous knowledge.

3.1. Model Validation

In model validation the process, the input/output data is presented to the trained FIS model for recording the level of prediction. The model is validated using another input/output data set, referred to as the *checking data set* which is used to control over fitting the data over the model**.** If collected data contains all the important features, then selection of testing data set can easily be done. However, in case of noisy measurements to the model, the training data may not include all of the representative features. For machine learning and validation, a large number of input-output data on MANET are required. In this thesis data-set is generated by network simulator for using in training phase and validation phase. NS2.34 gives an open simulation environment for research in the area of networking. The process of simulation is done by defining topology, developing models for network, by configuring the links, execution of model, analyzing the performance and then visualization.

4. STATE MODEL FORMULATION

4.1. Significant Input Variables

According to RFC 2501 [1], the networking context must be considered in which the performance of protocol is measured. The essential parameters that should be varied include:

- **Network size (node density-ND):** Measured in the number of nodes.
- **Network connectivity (maximum number of connections-MC):** The average degree of active connections (i.e. the average number of active neighbors of a node)
- **Topological rate of change (mobility speed-NM):** The speed with which a network's topology is changed
- **Halt in rate of topological change (pause time-PT):** How does a protocol perform while a node halts during changing topology?
- **Traffic patterns (data rate-NP):** To predict the effectiveness of a protocol for adapting non-uniform traffic patterns.

The state variables of the MANET system model

The state variables of MANET system model are defined as:

$$X(k)=\begin{bmatrix} ND \\ NC \\ NP \\ PT \\ NM \\ \\ \end{bmatrix}$$

Where, ND represents the node density which shows the total available active and passive nodes, NC represents the average degree of active connections, NP represents number of packets transferred in unit time by a node, PT represents the pause time which shows the halt of an active node during its movement, NM represents movement speed of any particular node in a particular given range

4.2. Significant Output Variables

As per RFC 2501 [1], the following is a list of quantitative metrics that can be used to assess the performance of any routing protocol:

Packet Delivery Ratio (PDR)

Average number of data packets transmitted or delivered. This can be thought of as a measurement the protocol efficiency for delivering data within the network.

Average End-to-end delay (AE2ED)

Statistical measures of data routing performance (e.g., means, variances, distributions) are important. These are the measures of a routing policy effectiveness.

Overhead

Average number of control packets transmitted over total data packets delivered. This measures the packet efficiency of the protocol in expending control overhead to delivers data. In other words, anything that is not data packet is control overhead.

The state output variables of the MANET system model

The state output variables of the MANET system model are defined as:

$$Y(k) = \begin{bmatrix} PDR \\ AE2ED \\ Overhead \end{bmatrix}$$

Calculating PDR [1]

- There are two lists, one of received and one of sent CBR packets with the agent type AGT
- For the *sentPktList*, store values for transmission time and packet sequence number
- store the receiving time and the sequence packet number in the *rcvPktList*
- Two counters, named *rcvPkts* and *sentPkt*, are used to calculate the PDR

PDR = Total data packets received / Total data packets sent

Calculating AE2ED [1]

- For every packet in the *sentPktList*, search its sequence number in the *rcvPktLis* and store the transmission time
- For each successful matching, extract the receiving time of that packet and calculate the end-to-end delay
- To find the AE2ED , sum all the delays and divide by the number of *rcvPkts*

AE2ED =∑(Time Received –Time Sent) / Total Data Packets Received

Calculating Overhead [1]

- For counting all sent events with agent type RTR and any control packet that the routing protocol generates
- To calculate the routing load , divide the sum of all control routing packets by the number of *rcvPkts*

Overhead = Total control packets / Total data packets received

The state space equations are defined by equation (4.1), equation (4.2), equation (4.3) &equation (4.4).

Table 1 Simulation Parameters [1]

Parameters	Value
Channel	Wireless Channel
Propagation Model	Two Ray Ground
Network Interface	Wireless Phy
Mac Layer	IEEE 802.11
Interface Queue	DropTail/Priority Queue
Link Layer	LL
Antenna	Omni Directional Antenna
Interface Queue length	50
Routing Protocol	DSR
Simulation Time	100 sec
Number of Nodes	12-111
Simulation Area	X=1000 m , y=1000 m
Speed	5-203 m/sec
Mobility Model	RPGM
Pause Time	5.0 -203.0 sec
Traffic Type	CBR
Packet Size	512 bytes
Rate	10 -505 packets/ sec
Number of Connections	4-103

In this paper, the experimental data is generated using NS2.34 under the environmental conditions, shown in table 1. The simulation parameters and respective values are shown in table 1. According to table the protocol for routing is used DSR; however any routing protocol can be chosen for data routing. The simulation has been run for 100 seconds; however the simulation time may vary as per requirement. The simulated data is collected for number of nodes (node density) from 12 to 111 with unit increment, maximum number of connections out of total node density from 4 to 103 with unit increment, Data rate from 10 packets/second to 505 packets/second with increment of 5 packets/second, pause time from 5 seconds to 203 seconds and mobility speed from 5 meter/seconds to 203 meter/seconds; the simulated data has been generated for proposed work under above described values; However, the values may be chosen randomly. The geographical area was provided 1000 square meters for node movement. The traffic generated by the network was considered with constant bit rate, this may be variable. The data packet size was kept fixed as 512 bytes.

5. CLASSIFICATION OF DATA SET

The simulated data obtained in table 1 , has been categorized based on the performance using k-means clustering algorithm. The goal of *this* clustering is to partition the data observed in MANET system model into k (*k=3)* groups such that the within-group sum-of-squares is minimized. In the algorithm, the observations have been assigned to its closest group, usually using the sqEuclidean among the observation and the cluster centroid. The procedure is to calculate the new centroid of cluster using assigned objects. The idea of clustering is to classify the operational data into different groups; one may be the higher performing group, medium performing group & lower performing groups. The training data set has been classified into three clusters for three state output variables PDR, AE2ED and NRL. Therefore in PDR,C1 is lower performing cluster, C2 is higher performing cluster and C3 is medium performing cluster. In AE2ED, C1 is lower performing,C2 is medium performing & C3 is higher performing cluster. Similarly, in Overhead, C1 is medium performing, C2 is higher performing and C3 is lower performing clusters.

6. FORMULATION OF THE SYSTEM MODEL

The system model for MANET has been formulated for addressing the anomalies , shown in figure 3. The system model consists of state variables & output variables. The working of the MANET system model is as follows:

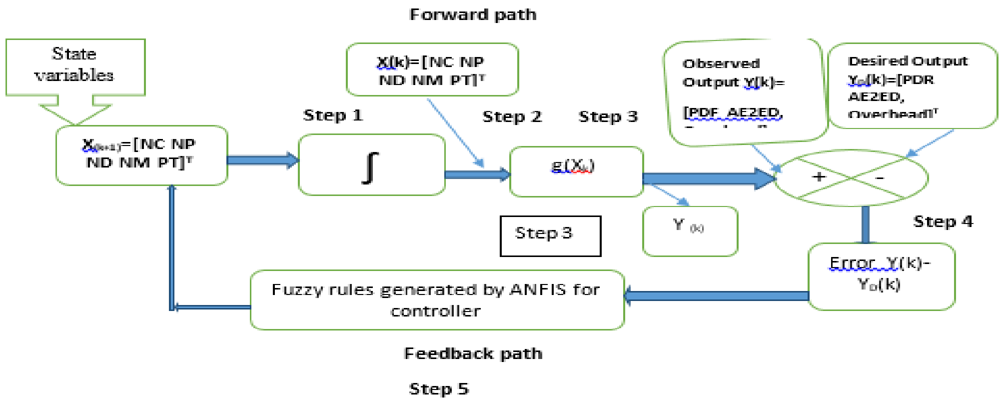

Figure 3 Model formulation for MANET System

The state equation of the MANET system model is represented by X(k) & state model equations are discussed in equation 4.3 and equation 4.4. The state equation of the MANET system model is defined as set of five state variables such as maximum connections which show available active connections, number of packets transferred per unit time through a node, density of nodes which shows the total available active and passive nodes, movement speed of a node in a given range & the pause time which shows the duration of halt for active node during its movement. The output equation of the MANET system model is defined using Y(k), the model is applied to all three performance evaluation parameters (PDR, AE2ED & Overhead).

The state of the model consists of different components as per following description:

A) State variables are:

NC is Number of Connections, NP is Number of Packets generated or Data Rate, ND is the Node Density, NM is the Node Mobility, PT is Pause Time

B) State output variables are:

PDR is Packet Delivery Ratio, Overhead is Normalized Routing Load, and Delay is Average end to end delay.

C) The system variables are defined as follows:

- X (k+1) is state of MANET at k+1, X (k) is the state of MANET at k
- Y (k) is observed performance of MANET at k, g is the function, which is determined using ANFIS, Y_D (k) is the expected performance of MANET system model, ∫ (Integration function).

The non-linear output models are implemented using ANFIS for each output separately. The model is divided into two parts forward path and feedback path. In this chapter the implementation of forward path is implemented, shown in figure 3.

In forward path implementation, first the simulated data set of 100 observations is classified using k-means into three groups as discussed in Chapter 4. The figure 5.2 shows the MANET system model for PDR.

The working of the model is as follows:

Step 1:

In this thesis, MANET model is simulated under 100 heterogeneous network conditions using NS2.34 network simulator and mobility generator tool (Bonnmotion 1.4). There are 100 observations obtained for three performance evaluation metrics (PDR, AE2ED & Overhead).

Step2:

The whole dataset has been classified using k-means clustering algorithm into three broad clusters (lower, medium & higher), each based on performance metrics mentioned in step 1.

Step 3:

The state of the MANET system model is defined by state vector X (k) comprising of five state variables: ND, NC, NP, PT & NM. The output vector Yk comprises of 3 output variables (PDR, Overhead & AE2ED)

Step 4:

For training the model, simulated input/output dataset of 60 scenarios is used. The ANFIS generates 243 fuzzy rules using Gaussian membership function which maps the inputs to the outputs. To achieve the zero tolerance level of error, the model is trained & converged after 100 epochs.

Step 5:

The model is validated by passing another input/output data set of 40 scenarios. The model is validated successfully at reasonably satisfactory level.

Step 6:

The MANET is system has been described as a MIMO (Multi Input Multi Output) system, therefore requires design of controllers for each of the three outputs (PDR, AE2ED & Overhead). The controller adjusts the values of input variables for minimizing the difference between observed performance & actual performance. The controller controls the behavior of the mobile ad-hoc network intelligently in an adaptive .

6.1. MANET System Model for PDR

The internal structures of MANET system model for PDR is shown in figure 4. It is shown in figure that the model is developed using sugeno method with 5 state variables with three membership functions MF1 as low , MF2 as medium & MF3 as higher and 3 state output variables with 243 output variations

The sample fuzzy rules of MANET system model for state output variables PDR are shown in figure 5

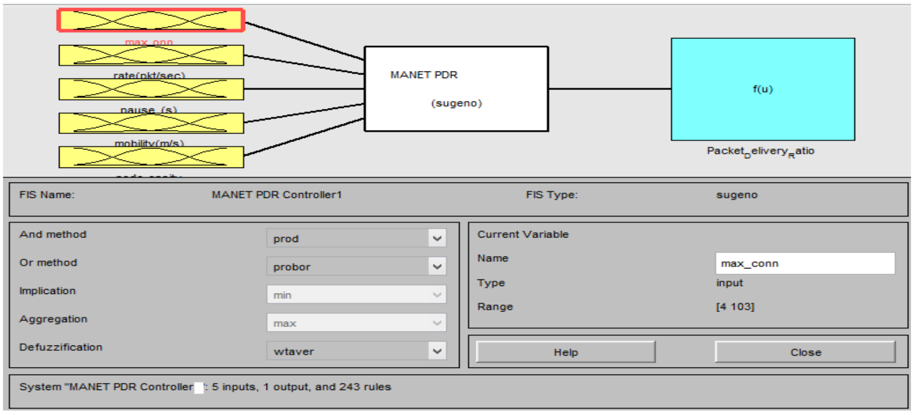

Figure 4 MANET system model for Packet Delivery Ratio (PDR)

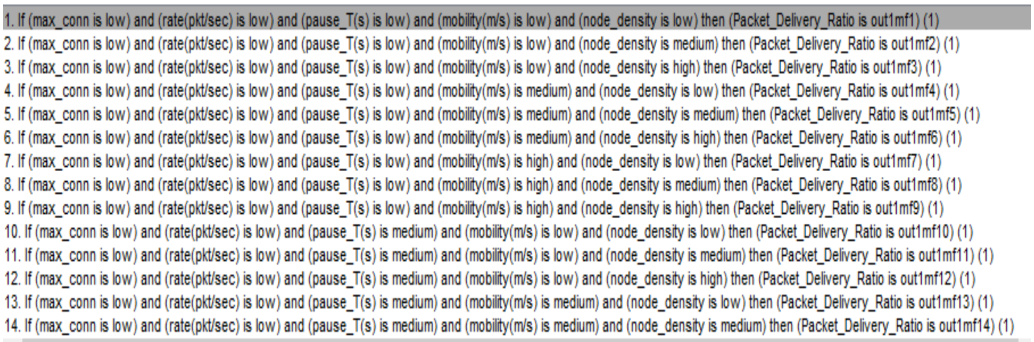
1. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is low) and (node_density is low) then (Packet_Delivery_Ratio is out1mf1) (1)
2. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is low) and (node_density is medium) then (Packet_Delivery_Ratio is out1mf2) (1)
3. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is low) and (node_density is high) then (Packet_Delivery_Ratio is out1mf3) (1)
4. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is medium) and (node_density is low) then (Packet_Delivery_Ratio is out1mf4) (1)
5. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is medium) and (node_density is medium) then (Packet_Delivery_Ratio is out1mf5) (1)
6. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is medium) and (node_density is high) then (Packet_Delivery_Ratio is out1mf6) (1)
7. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is high) and (node_density is low) then (Packet_Delivery_Ratio is out1mf7) (1)
8. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is high) and (node_density is medium) then (Packet_Delivery_Ratio is out1mf8) (1)
9. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is low) and (mobility(m/s) is high) and (node_density is high) then (Packet_Delivery_Ratio is out1mf9) (1)
10. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is medium) and (mobility(m/s) is low) and (node_density is low) then (Packet_Delivery_Ratio is out1mf10) (1)
11. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is medium) and (mobility(m/s) is low) and (node_density is medium) then (Packet_Delivery_Ratio is out1mf11) (1)
12. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is medium) and (mobility(m/s) is low) and (node_density is high) then (Packet_Delivery_Ratio is out1mf12) (1)
13. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is medium) and (mobility(m/s) is medium) and (node_density is low) then (Packet_Delivery_Ratio is out1mf13) (1)
14. If (max_conn is low) and (rate(pkt/sec) is low) and (pause_T(s) is medium) and (mobility(m/s) is medium) and (node_density is medium) then (Packet_Delivery_Ratio is out1mf14) (1)

Figure 5 Fuzzy rules for PDR

7. RESULTS OF TRAINING & VALIDATION OF MODEL FOR PDR

For training the model, simulated input/output dataset of 60 scenarios is used. The ANFIS generates 243 fuzzy rules using Gaussian membership function which maps the inputs to the outputs. To achieve the zero tolerance level of error, the model is trained & converged after 100 epochs. The model is validated by passing another input/output data set of 40 scenarios. The model is validated successfully at reasonably satisfactory level. The results are shown below:

PDR

Model type	: Sugeno
Data points	: 60
Epochs	:100
Membership function	: Gaussian MF
Membership function type	: linear
Training optimization method	: hybrid
Converged value of RMS error	:0.1

In summary, For training the model, set of simulated input/output data for 60 scenarios is passed. The ANFIS generates 243 fuzzy rules using Gaussian membership function which maps the inputs to the outputs. To achieve the zero tolerance level of error, the model is trained & converged after 100 epochs in PDR controller model.

8. CONCLUSIONS

In this paper, MANET model is simulated and behavior is compared under 100 heterogeneous network conditions using NS2.34 network simulator and mobility generator tool (Bonnmotion 1.4). There are 100 observations obtained for three performance evaluation metrics (PDR, AE2ED & Overhead). It is observed that the behavior of MANET is having uncertainty i.e. it is difficult to identify the network conditions (number of connections which show available active connections, number of packets transferred per unit time by a node, density of nodes which shows the total available active and passive nodes, speed of movement of any particular node in a particular given range, the pause time shows the halt of any active node during movement) in which the performance is good or bad. It seems good in one but bad in others.

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