Chapter 6

Fuzzy Logic Based AODV – Hybrid Simulation

This chapter describes an overview of optimization of power control for Reactive Routing protocol AODV in wireless ad hoc network using the soft computing technique. Power optimization is attempted using adaptive value selection of the hello interval by Fuzzy logic. Simulation study has been done using MATLAB-QUALNET. A comparative simulation study of proposed hybrid technique is discussed for a sample ad Hoc configuration with 50 nodes against the standard value of 1sec suggested by classical AODV standards.

In the recent years, research efforts have been focusing on improving the performance of routing protocols in Mobile Ad-Hoc Network (MANET). The Internet Engineering Task Force (IETF) [1] created a MANET working group (WG) to deal with issues related to the complexity of constructing MANET routing protocols. These protocols are classified into two classes based on the time when routing information is updated, the Proactive Routing Protocols (PRP) and Reactive Routing Protocols (RRP). The WG may also consider a converged approach such as hybrid routing protocols.

An ad hoc wireless network has no fixed networking infrastructure. It consists of multiple, possibly mobile, nodes that maintain network connectivity through wireless communications. Such a network has practical applications in areas where it may not be economically practical or physically possible to provide a conventional networking infrastructure. The nodes in an ad hoc wireless network are typically powered by batteries with a limited energy supply. One of the most important and challenging issues in ad hoc wireless networks is how to conserve energy, maximizing the lifetime of its nodes and thus of the network itself. Since routing is an essential function in these networks, developing power aware routing protocols for ad hoc wireless networks has been an intensive research area in recent years. Many power-aware routing protocols have been proposed from a variety of perspectives [2].

6.1 Classical AODV

Ad hoc On-Demand Distance Vector (AODV) routing is a routing protocol for mobile ad hoc networks and other wireless ad-hoc networks. It is jointly developed in Nokia Research Centre of University of California, Santa Barbara and University of Cincinnati by C. Perkins [3].

The Ad Hoc On-demand Distance Vector Routing (AODV) protocol [4] is a reactive unicast routing protocol for mobile ad hoc networks. As a reactive routing protocol, AODV only needs to maintain the routing information about the active paths. In AODV, routing information is maintained in routing tables at nodes. Every mobile node keeps a next-hop routing table, which contains the destinations to which it currently has a route. A routing table entry expires if it has not been used or reactivated for a pre-specified expiration time. Moreover, AODV adopts the destination sequence number technique used by DSDV in an on-demand way.

In AODV, when a source node wants to send packets to the destination but no route is available, it initiates a route discovery operation. In the route discovery operation, the source broadcasts route request (RREQ) packets. A RREQ includes addresses of the source and the destination, the broadcast ID, which is used as its identifier, the last seen sequence number of the destination as well as the source node's sequence number. Sequence numbers are important to ensure loop-free and up-to-date routes. To reduce the flooding overhead, a node discards RREQs that it has seen before and the expanding ring search algorithm is used in route discovery operation. The RREQ starts with a small TTL (Time-To-Live) value. If the destination is not found, the TTL is increased in following RREQs.

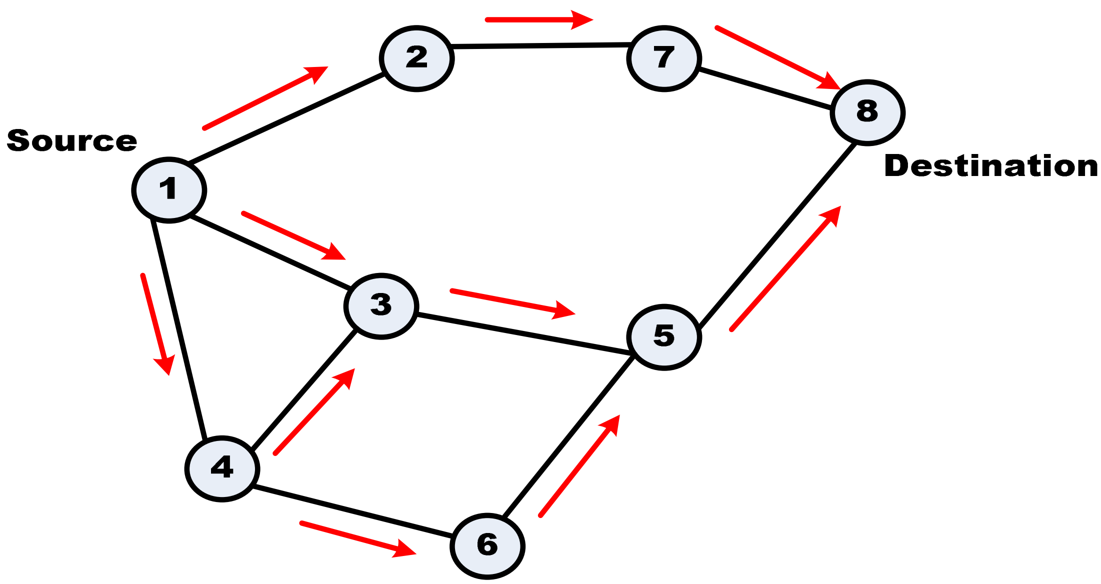


Figure 6.1: the Route Request packets flooding in AODV

Figure 6.1 shows the Route Request Packets flooding in AODV. Where, each node maintains a cache to keep track of RREQs it has received. The cache also stores the path back to each RREQ originator. When the destination or a node that has a route to the destination receives the RREQ, it checks the destination sequence numbers it currently knows and the one specified in the RREQ. To guarantee the freshness of the routing information, a route reply (RREP) packet is created and forwarded back to the source only if the destination sequence number is equal to or greater than the one specified in RREQ. AODV uses only symmetric links and a RREP follows the reverse path of the respective RREP. Upon receiving the RREP packet, each intermediate node along the route updates its next-hop table entries with respect to the destination node. The redundant RREP packets or RREP packets with lower destination sequence number will be dropped. **Figure 6.2** shows the Route Reply Packet for AODV routing protocol.

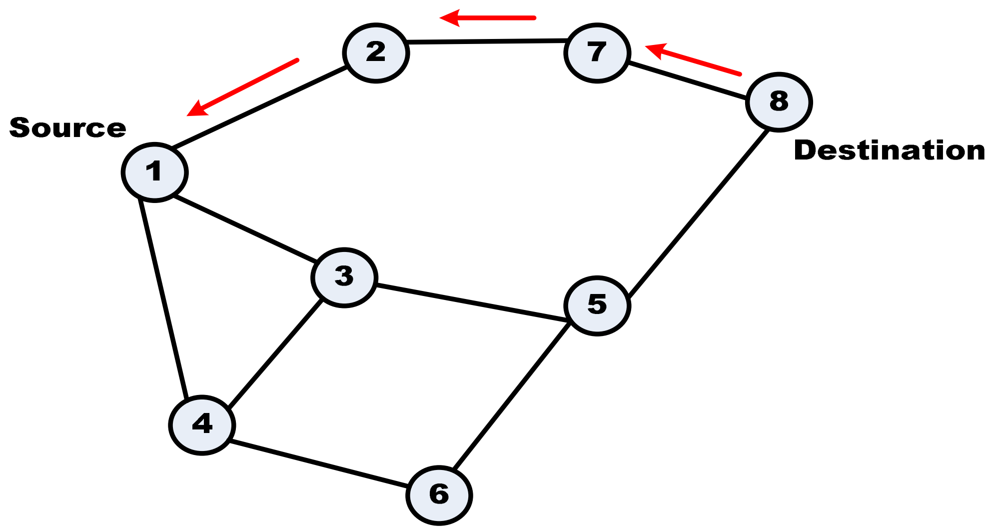


Figure 6.2: Forwarding of Route Reply packet in AODV

In AODV, a node uses hello messages to notify its existence to its neighbors. Therefore, the link status to the next hop in an active route can be monitored. When a node discovers a link disconnection, it broadcasts a route error (RERR) packet to its neighbors, which in turn propagates the RERR packet towards nodes whose routes may be affected by the disconnected link. Then, the affected source can re-initiate a route discovery operation if the route is still needed. Nodes monitor the link status of next hops in active routes. When a link breakage in an active route is detected, a RERR message is used to notify other nodes of the loss of the link. In order to enable this reporting mechanism, each node keeps a list, containing the IP address for each its neighbours that are likely to use it as a next hop towards each destination.

6.2 Fuzzy Inference System(FIS) :Introduction

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in the previous sections: membership functions, fuzzy logic operators, and if-then rules [5].

Fuzzy logic has been applied in control systems either to improve performance or to avoid difficult mathematical problems [6, 7].

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic. But in a wider sense, which is in predominant use today, fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL. What is important to recognize is that, even in its narrow sense, the agenda of fuzzy logic is very different both in spirit and substance from the agendas of traditional multivalued logical systems.

Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in AI, what is missing in such systems is machinery for dealing with fuzzy consequents and/or fuzzy antecedents. In fuzzy logic, this machinery is provided by what is called the calculus of fuzzy rules. The calculus of fuzzy rules serves as a basis for what might be called the Fuzzy Dependency and Command Language (FDCL). Although FDCL is not used explicitly in the Fuzzy Logic Toolbox [8], it is effectively one of its principal constituents. In this connection, what is important to recognize is that in most of the applications of fuzzy logic, a fuzzy logic solution is in reality a translation of a human solution into FDCL. What makes the Fuzzy Logic Toolbox so powerful is the fact that most of human reasoning and concept formation is linked to the use of fuzzy rules. By providing a systematic framework for computing with fuzzy rules, the Fuzzy Logic Toolbox greatly amplifies the power of human reasoning.

Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system. In this section we seek to provide a philosophy of how to approach the design of fuzzy controllers.

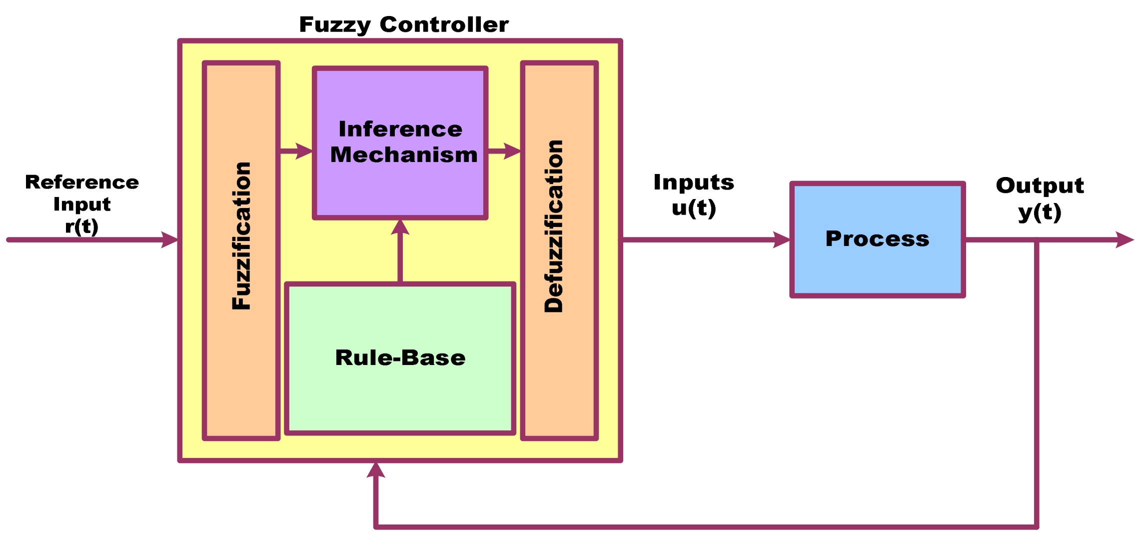


Figure 6.3: Fuzzy control Architecture

The fuzzy controller block diagram is given in **Figure 6.3**, where we show a fuzzy controller embedded in a closed-loop control system.

The fuzzy controller has four main components:

- The "rule-base" holds the knowledge, in the form of a set of rules, of how best to control the system.

- The inference mechanism evaluates which control rules are relevant at the current time and then decides what the input to the plant should be.
- The fuzzification interface simply modifies the inputs so that they can be interpreted and compared to the rules in the rule-base.
- The Defuzzification interface converts the conclusions reached by the inference mechanism into the inputs to the plant.

In the Fuzzy Logic Toolbox [8], fuzzy logic should be interpreted as FL, that is, fuzzy logic in its wide sense. The basic ideas underlying FL are explained very clearly and insightfully in the Introduction. What might be added is that the basic concept underlying FL is that of a linguistic variable, that is, a variable whose values are words rather than numbers. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution.

6.3 FIS :State of Art

In recent years a number of power-aware routing protocols have been proposed. In [9] the authors outline the key concepts of several proposed solutions and provide an analysis of them. [10] Proposes five power-aware metrics that can be used to classify routing protocols. In [11] the authors briefly review landmark papers for each protocol layer and define several metrics for studying power-aware routing protocols. [12] Addresses design challenges of energy-efficient protocols in various layers and places special emphasis on cross-layer design of these protocols.

With the goal of reducing power consumption while ensuring effective connectivity for the overall network, connectivity-based protocols look beyond issues of transmission [13]. Maintaining effective connectivity for a wireless network is essential to almost any operation. If the connectivity of a wireless network is too dense, it causes frequent interference among nodes. If the connectivity is too sparse, the network is sensitive to node or link failure. We divide connectivity based protocols into two categories: topology control and passive energy saving. Topology control protocols adjust nodes' transmitting power to save energy while maintaining effective network connectivity. Passive energy saving protocols save energy by simply turning off some idle nodes, since energy consumption when a node's radio is idle is not negligible.

The reactive (on-demand) routing protocols are much more dynamic than infrastructured networks. Instead of periodically updating the routing information, the reactive routing protocols update routing information when a routing requirement is presented, consequently reducing the control overhead, especially in high mobility networks where the periodical update will lead to significant useless overhead [14].

In ad hoc position-based routing protocols, nodes broadcast periodic beacon packets to maintain up-to-date position information of their neighbors within their transmission range for making effecting routing decisions. Receiving nodes list all known neighbor nodes with their position information in their neighbor table. Due to node mobility which caused frequent network topology changing especially in highly dynamic network like ad hoc, neighbor relationship changes frequently and local topology rarely remains static. Using periodic beaconing lead to inaccurate node's neighbor table and the routing protocol may take suboptimal decisions and not route packets via the best located neighbor within node's transmission range. [15, 16] has improved the reliability of neighbors table by optimizing the time between the transmissions of beacon packets in order to mitigate the observed drawbacks of periodic beaconing. Optimization is based on the correlation between the node mobility and periodic beaconing of beacon packet transmission using fuzzy logic controller [17].

[18] Has applied fuzzy logic system to master/controller election for each cluster. A self-reconfiguring topology is proposed to manage the mobility and recursively update the network topology. They also modify the mobility management scheme with hysteresis to overcome the ping-pong effect. Simulation results show that our scheme performs much better than the existing algorithm

If a node does not make any change in its routing table since the last update, it has to send an idle HELLO message to ensure connectivity. On receiving an update message, a node modifies its distance table and looks for better routes using updated information. Any new route thus found is relayed back to the node from which the update message was received. On receiving an acknowledgment for an update message, a node updates its message retransmission list [19].

6.4 Fuzzy AODV[1]

In AODV [20, 21] to investigate the new path or existing path is still available or not that it checks by continually broadcasting the Hello messages (Beacon messages) periodically. These messages helped to get a clearer view of the local network topology, it also have some drawbacks for the whole network in general. Increased number of these messages consumes network resources and bandwidth, increases collisions and interferences with data and control messages and consumes the limited nodes battery life during sending and receiving operations. If we decrease the number of hello messages results in a time gap between a link failure event and its detection. In essence, it means that the protocol designer has to trade-off sending these messages carefully to represent the real needs for connectivity updating.

[1] Presented a Paper in **INTERNATIONAL CONFERENCE "Performance Optimization of Reactive Routing Protocol Using Fuzzy Logic for MANET in Qualnet"** at a **WORLDCOMP 2010 World Congress In Computer Science, Computer Engineering And Applied Computing** called **" ICWN'10"** held at LAS WEGAS,USA on 12-14th July, 2010.

The maximum time period that can transpire before the node broadcasts the next Hello message is adaptively optimized, which affects the number of sent Hello messages during a fixed period of time. Optimization is based on the correlation between the topology reconstruction and periodical interval for the Hello message transmission.

[22] Presents a novel routing scheme for ad hoc networks that applies fuzzy logic to differentiated resource allocation, considering traffic importance and network state. Messages are routed over zero or more maximally disjoint paths to the destination: important packets may be forwarded redundantly over multiple disjoint paths for increased reliability, while less important traffic may be suppressed at the source. The performance of fuzzy routing is evaluated using simulation, and is compared to DSR and SMR wireless routing protocols.

[23] Balakrishnan and Johnson (2005) used fuzzy reasoning to allow every node to decide whether or not to forward the traffic to the next node in the route depending on its remaining energy and the traffic intensity. In this method, the source nodes will not know the status of the non-forwarder nodes, making the possibility of data losing in the network to be high. To overcome that, Liang and Ren (2005) and Liang (2005) [24] used fuzzy reasoning to make it possible for the source node to add adjacent nodes to the route depending on the distance between the adjacent node and the destination, the adjacent node remaining energy, and its degree of mobility. In [25] Xia and Liang (2005), the authors enhanced the previous method to balance traffic delay and nodes energy by electing the nodes with the highest three possibilities as the relay nodes and then electing the node with the highest possibility as the target node.

In [26] Yusuf and Haider (2005), the authors used more advanced technique by making the forwarding decision to be the costs of the links. Links with the highest cost will be chosen at forwarding time. To calculate links costs, authors used fuzzy reasoning with five energy and traffic metrics. However, using five inputs to the FRA needs to be carefully investigated to demonstrate the inter-relationship between them. Validating this relationship is extremely difficult.

In this technique the fuzzy reasoning is used to dynamically configure the protocols parameters instead of using static values. The dynamical configuration can adapt to the changing of the network topology and improve the protocol performance. On the other hand using static parameters for the protocols in ad hoc environments that suffer from frequent change of network topology and different traffic intensity may degrade the routing protocols performance. Wang et al. (2005) used a fuzzy reasoning to dynamically configure five routing parameters of AODV (Ad hoc On-demand Distance Vector) routing protocol [27]. They used mathematical models to represent nodes moving mode and their traffic mode. These models were used to categorize the network environments to nine categories. The fuzzy reasoning was used to estimate the nodes membership degree in these environments. Depending on the node membership degree, the values of the protocol parameters are increased or decreased.

The transmission power, the strength by which the signal is sent, is a main parameter that determines the number of neighbors for nodes in ad hoc network [28, 29]. If the transmission power of a node is too low, then the signal will reach a few neighbors only and its links with those neighbors may weak and easy to break. The Hello interval must be small enough to get a fast update for neighborhood changes. The high transmission power leads to a high average number of its neighbors which increases the lifetime of its links and the hello interval must be long due to fewer changes in the node's neighborhood. In the MANET probability of the link breakages increases due to the topology changes frequently. The high speed of a node results in a high probability of losing some of the current neighbors and acquiring new ones. As the nodes moves fast their links lifetime with their neighbors will be small. Hello Interval time is small to send more Hello messages to check the expected links breaks.

The Fuzzy Inference System (FIS) [06] is a decision making logic that employs a set of fuzzy IF-THEN rules. The optimal Hello Interval determined by FIS with sufficient rules. Inputs of the fuzzy Inference System are Transmission power and Mobility of the node (speed) and the output of the system is hello interval which is shown in the **Figure 6.4.**

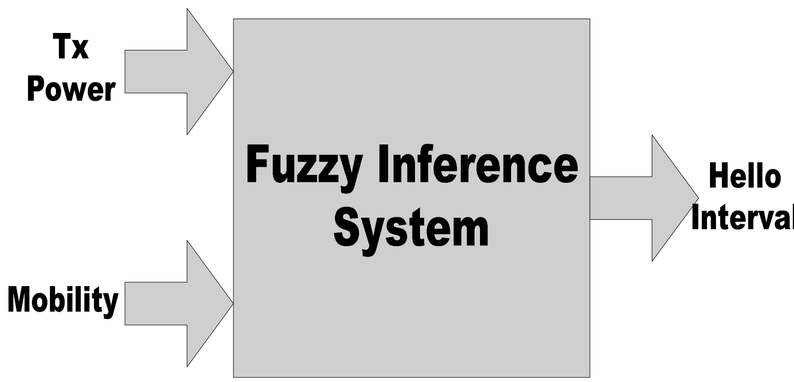


Figure 6.4: Fuzzy Inference System with respective inputs and outputs.

Variables with the MBF and ranges are defined in **Table 6.1**. Input Tx Power has Gaussian type MBF with the 8mw as a low linguistic term, 11 mw for medium with triangular MBF, 14 mw for high term with Gaussian MBF.

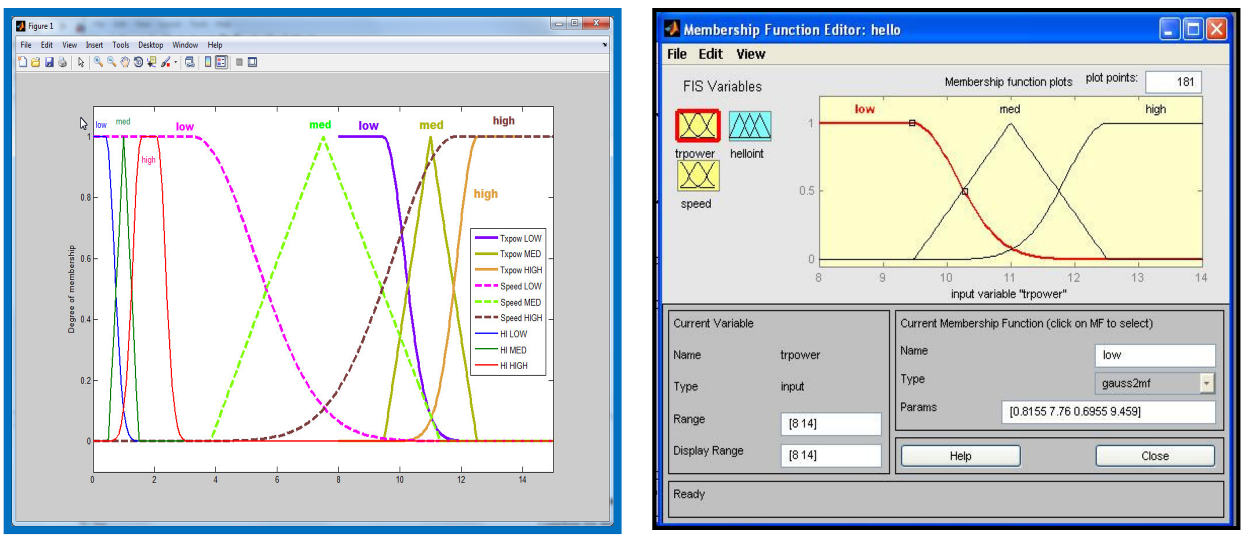
Parameters	Input/ Output	Range	Types of Linguistic Terms & Types of MBF		
Tx Power	Input	(8-14)	8 mw Low (Gaussian)	11 mw Medium (Triangular)	14 mw High (Gaussian)
Mobility	Input	(5-15)	5m/s Low (Gaussian)	11 m/s Medium (Triangular)	15 m/s High (Gaussian)
Hello Interval	Output	(0- 2)	0 sec Low (Gaussian)	1 sec Medium (Triangular)	2 sec High (Gaussian)

Table 6.1: Linguistic Terms and Its types of MBFs

The simplest membership functions are formed using straight lines. Of these, the simplest is the triangular membership function, and it has the function name trimf. This function is nothing more than a collection of three points forming a triangle. Two membership functions are built on the Gaussian distribution curve: a simple Gaussian curve and a two-sided composite of two different Gaussian curves. The two functions are gaussmf and gauss2mf [8].

The generalized bell membership function is specified by three parameters and has the function name gbellmf. The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned. Because of their smoothness and concise notation, Gaussian and bell membership functions are popular methods for specifying fuzzy sets. Both of these curves have the advantage of being smooth and nonzero at all points.

A Membership Function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept.



(a): MBF Library **(b): MBF Editor: FIS for Hello Interval (HI)**

Figure 6.5: Membership Functions Selection for Fuzzy Inference System (Fuzzy AODV)

Figure 6.5(a) shows the membership function for the two inputs Tx-power and the mobility also for the output hello interval of FIS. LOW and HIGH level of the membership function is of Gaussian type and the medium level is of the type of triangular MBF which is shown in **Figure 6.5(b).**

The fuzzy control rules of a two-input-single-output fuzzy system can be described as…

R_J: IF Txpower is x_1 AND Mobility is x_2, THEN Hello Interval=x_3

Where x1, x2, x3…are the linguistic terms of the input variables and the output variables.

Table 6.2 depicts Rule base with Hello interval as output and transmission power and mobility of the nodes as an inputs. Three Linguistic terms LOW, MEDIUM and HIGH is used for input and output variables.

Transmission Power	Mobility		
	Low	Medium	High
Low	Medium	Low	Low
Medium	High	Medium	Low
High	High	High	Medium

Table 6.2: Fuzzy Rule Base for Hello Interval (HI)

In MATLAB Surface Viewer, invoked using surfview('a'), is a GUI tool that lets you examine the output surface of a FIS stored in a file, *.fis, for any one or two inputs. Because it does not alter the fuzzy system or its associated FIS structure in any way, Surface Viewer is a read-only editor. Using the drop-down menus, you select the two input variables you want assigned to the two input axes (X and Y), as well the output variable you want assigned to the output (or Z) axis. **Figure 6.6** represents the FIS surface viewer which controls the area of interest

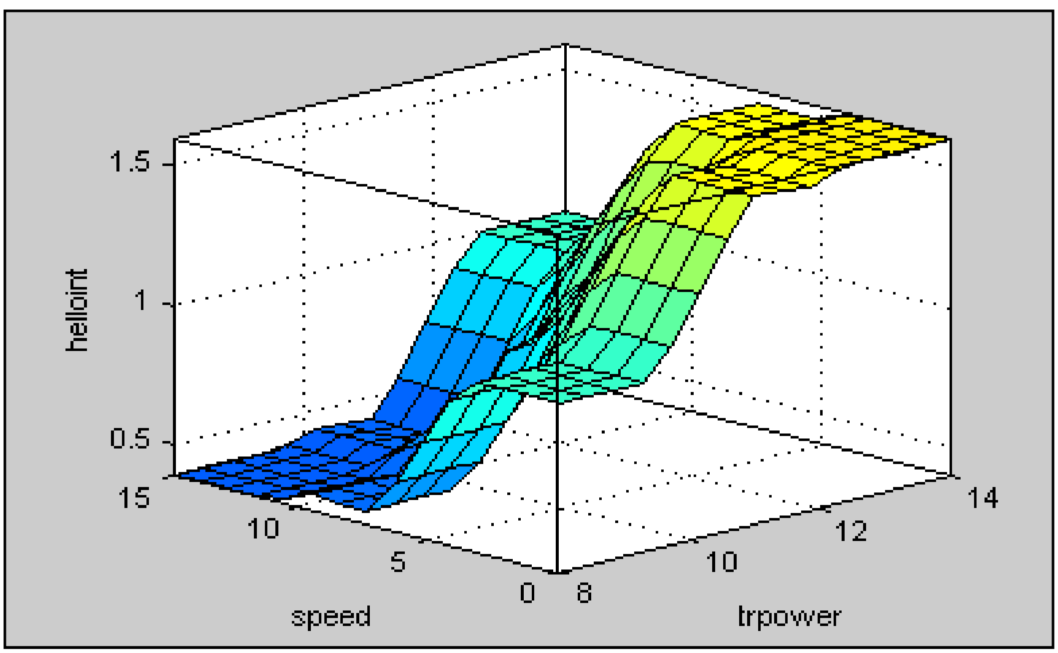


Figure 6.6: Surface Viewer for FIS Hello Interval (HI)

6.5 Fuzzy based performance optimization[2]

The simulation results were carried out in Qualnet 5simulator to evaluate the performance of the AODV routing protocol on the MANET with the 50 nodes with the parameters selection as follows in the Qualnet simulator [30].

The QualNet Developer IDE is a GUI based program for developing network scenarios that comes with QualNet 5.0. It can be used to visually design network scenarios and then run simulations of these networks. Although networks can be designed and simulated in a command-line fashion as well, on the Developer IDE package.

QualNet is a comprehensive suite of tools for modeling large wired and wireless networks. It uses simulation and emulation to predict the behavior and performance of networks to improve their design, operation and management [31]. QualNet enables users to: Design new protocol models, Optimize new and existing models, Design large wired and wireless networks using pre-configured or user-designed models, Analyze the performance of networks and perform what-if analysis to optimize them.

The **Figure 6.7 (a)** shows the scenario of the developed wireless ad-hoc network in the Qualnet 5 which has 50 nodes.

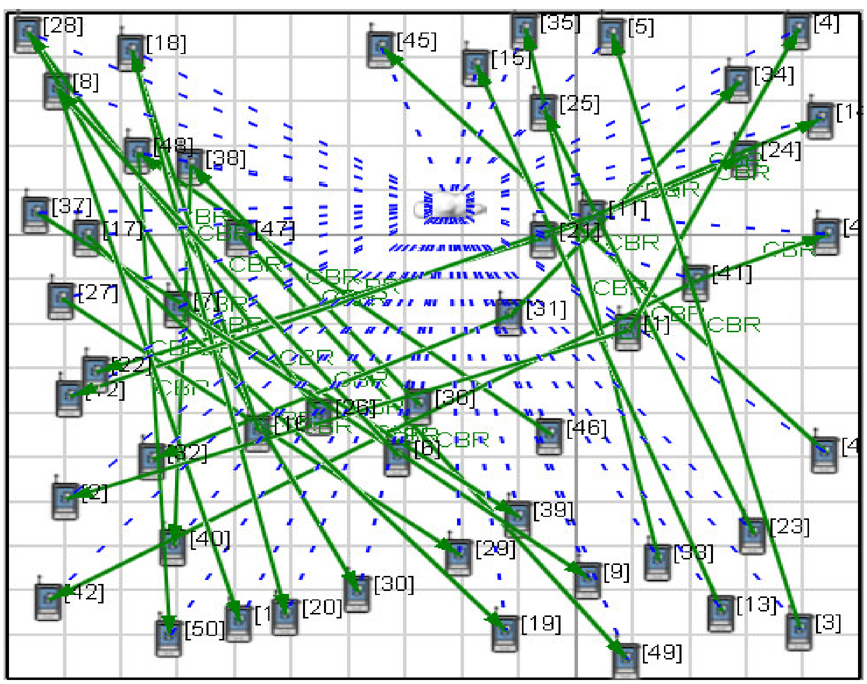


Figure.6.7 (a): Scenario Created For Wireless Ad-Hoc Network in Qualnet

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[2] **Published** in Proceeding of **International conference** Paper entitled **"Performance Optimization of Reactive Routing protocol Using Fuzzy Logic for MANET in Qualnet"** in the **WORLDCOMP'10**, The 2010 World Congress in Computer Science, Computer Engineering, and Applied Computing held on **July 12-15, 2010**, **Las Vegas, USA** in **ICWN'10: Wireless Networks Division page:167-171**.

The 40 nodes are generated for each protocol within the terrain of 1500m X 1500m and the random waypoint mobility is provided to realization as a real time simulation with the pause time of 30S, min speed of the 5mps and max speed of 20 mps. We have taken the network protocol as IPv4 and MAC protocol of the 802.11. The packet reception model is PHY 802.11b is considered here. The propagation channel frequency is 2.4 GHz, the two ray ground propagation model and omnidirectional antenna is considered. The traffic generated between some random nodes is CBR type. We have carried out the simulation for the simulation time of 300S. We have derived the simulation results based on the above performance metric using the fuzzy based decision for the hello interval and the normal hello interval for the network of 40 nodes and 30 nodes for the AODV Reactive protocol.

Figure 6.7 (b) shows the scenario of the wireless ad hoc network created with coverage range of each node which communicate with each other.

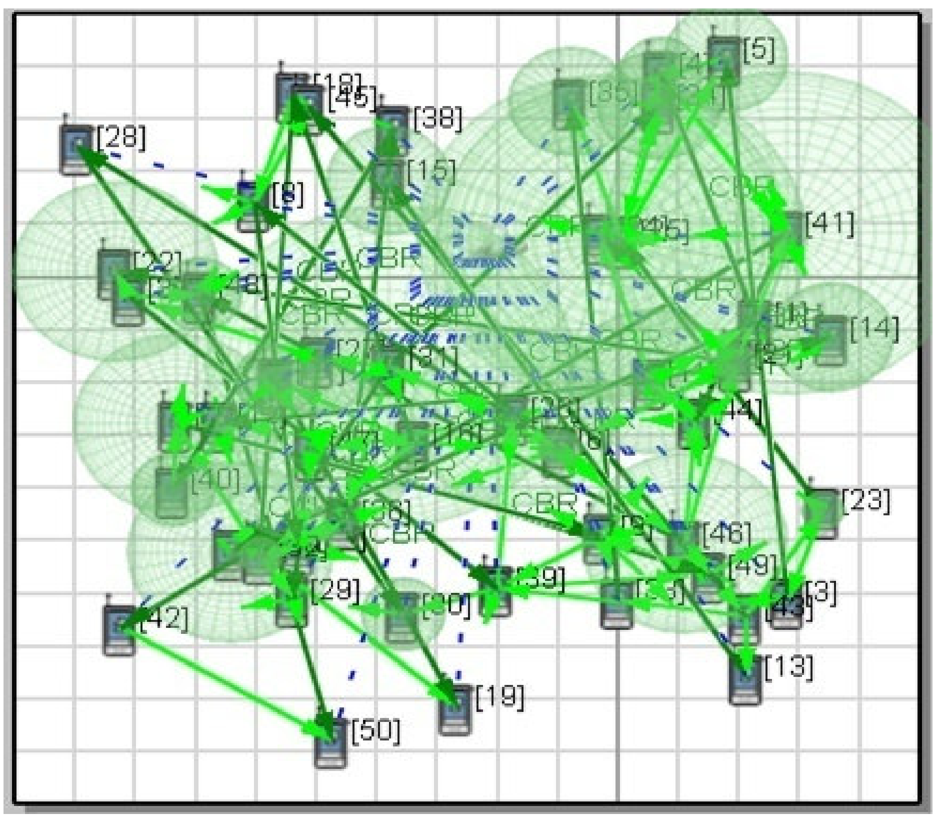


Figure.6.7 (b): Scenario Created For Wireless Ad-Hoc Network in Qualnet

AODV manages local connectivity using two parameters: hello interval and allowed hello loss. The Hello Interval (HI) specifies the time between two Hello messages; generally set to 1 second. If a neighbor does not receive any packets for more than allowed hello loss * hello interval seconds, the node should assume the link to this neighbor is broken. The recommended value for allowed hello loss is 2.

6.5.1 Proposed Procedure for Hybrid Simulation

The interfacing of FIS in MATLAB [08] and Wireless Network created in Qualnet [30] of 50 nodes is done offline. The algorithm (steps) of simulation is as follows…..

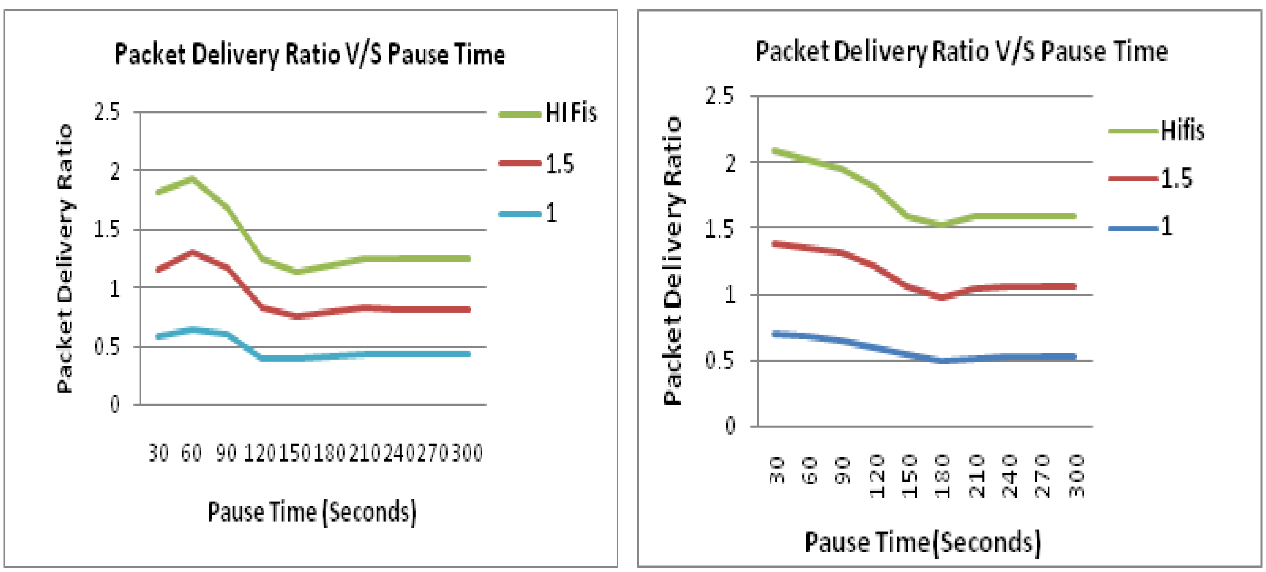
- Create the wireless network in the Qualnet simulator according to the required configurations.
- Apply the suitable routing protocol for the wireless network and also adjust the required configurations to the network and network nodes.
- Simulate the network and note down the results.
- Now to optimize the parameters for routing protocol, decide the input and output parameter range according to the dependencies of the situation of network nodes.
- Design the Fuzzy Inference System (FIS) for the given parameter as input or output in MATLAB.
- Evaluate the FIS in MATLAB according to the parameter of routing protocol and whatever output decided by FIS note down it.
- Apply the output of the FIS to the wireless network, and evaluate the performance of the network which is FIS based.
- Now compare the results of Routing protocol for FIS based and without FIS.

To evaluate the performance of routing protocols, both qualitative and quantitative performance metrics are needed. Routing protocols use several performance metrics to calculate the best path, evaluation of the performance of the network, for routing the packets to its destination [32, 33]. Here, four different quantitative metrics are used to compare the performance. They are

- **Packet Delivery Ratio (PDR):** The ratio of the number of data packets received by the receivers verses the number of data packets supposed to be received. This number presents the effectiveness of a protocol.
- **Average Throughput:** The throughput is defined as the total amount of data a receiver actually receives from the sender divided by the time between receiving the fast packet and last packet. This metric represents the total number of bits forwarded to higher layers per second. It is measured in bps. It can also be defined as the total amount of data a receiver actually receives from sender divided by the time taken by the receiver to obtain the last packet.
- **Average Jitter:** Jitter metric, which is used in this paper, is a quantifier of the changeability over time of the packet latency across a network and can be a measurement for the quality of a communication. A zero jitter shows a very high quality communication without any latency.

- **Received Packets:** It is the total number of data packets received by the destination nodes in the network.
- **Media Access Delay:** The time a node takes to access media for starting the packet transmission is called as media access delay. The delay is recorded for each packet when it is sent to the physical layer for the first time.
- **Routing overhead:** This metric describes how many routing packets for route discovery and route maintenance need to be sent so as to propagate the data packets.

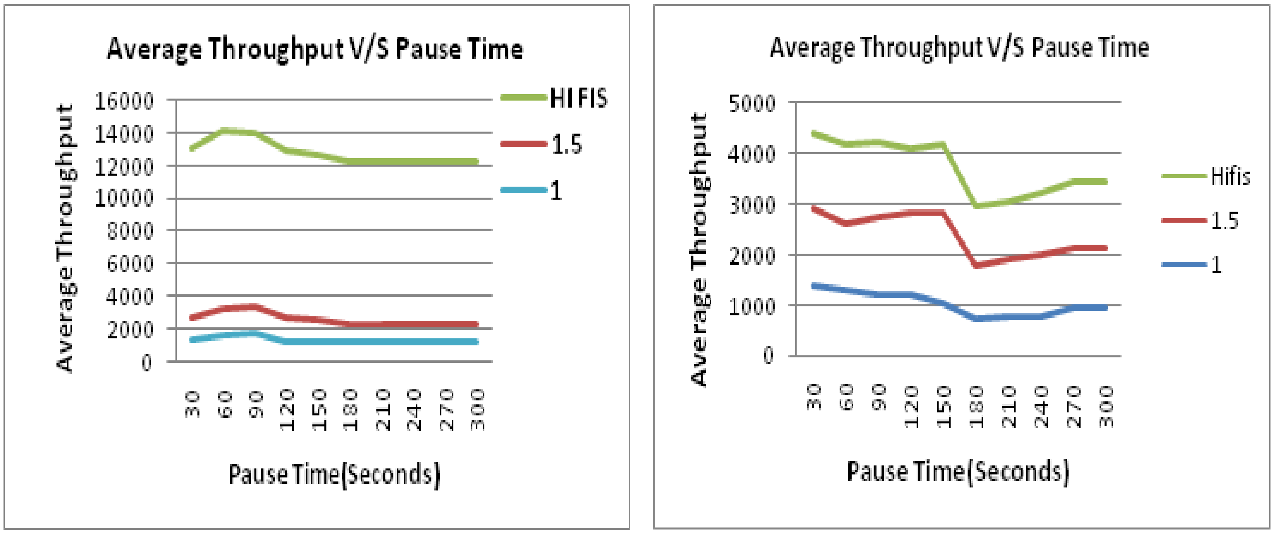
From this above performance metrics we have considered Packet Delivery Ratio (PDR), Average Throughput, Average Jitter, and Number of Received Packets for performance evaluation of the wireless network and applied routing protocol. **Figure 6.8** shows the packet delivery ratio of the AODV protocol for the number of nodes 30 and 40.The Packet Delivery Performance for the hello interval determined using FIS is better than the standard HI.



(a) for nodes=30 **(b) for nodes=40**

Figure 6.8: Average Packet Delivery Ratio V/S Pause time

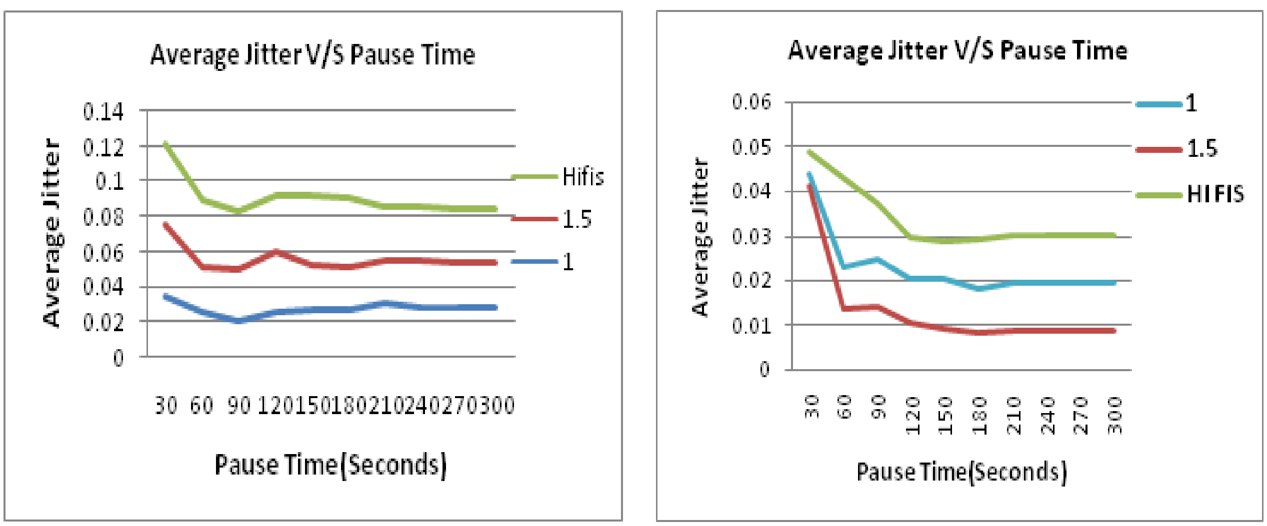
Figure 6.9 indicates that throughput and received packets performance for the FIS Hello interval is better than standard hello interval. As the network size increases average throughput of fuzzy based hello interval changes according to the situation while there is a minor change in the static value of the hello interval which is shown in **Figure 6.9 (a)** and **Figure 6.9(b).**



(a) for nodes=30 **(b) for nodes=40**

Figure 6.9: Average Throughput V/S Pause Time

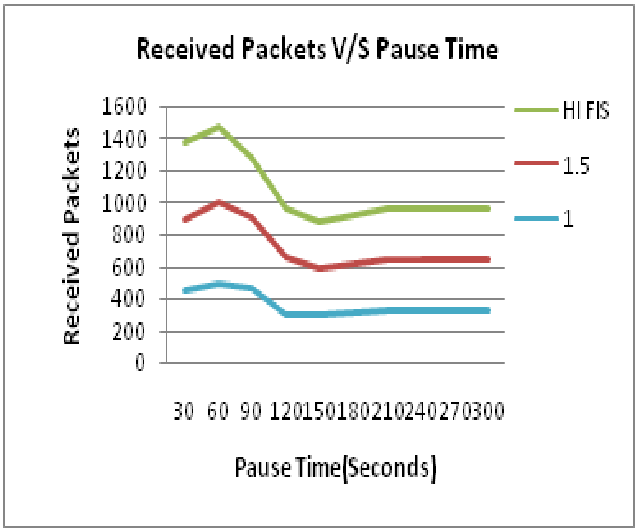
Effect of change in pause time on Average Jitter is shown in **Figure 6.10**. It is observed that the Average Jitter is increased when the FIS HI is used while it is less for the static value of the hello interval as 1 and 1.5.As the node density increases the average jitter decreases for the fuzzy based Hello interval but not much difference for the static values, which can be observe by comparing the **Figure 6.10(a)** and **Figure 6.10(b).**

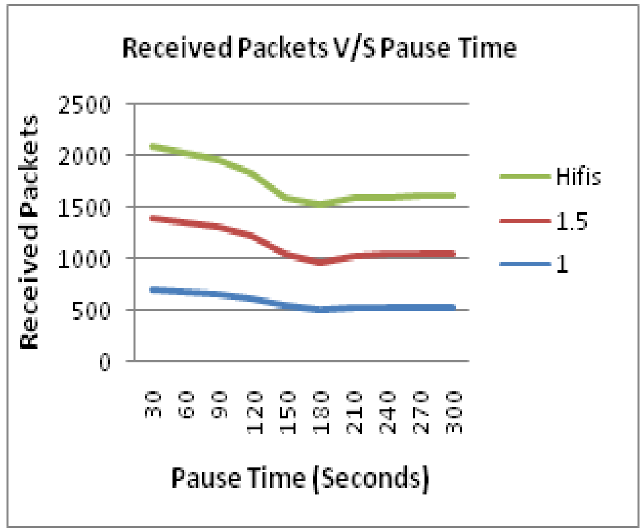


(a) for nodes=30 **(b) for nodes=40**

Figure 6.10: Average Jitter V/S Pause Time

Figure 6.11 shows the effect of pause time on the average received packets with and without fuzzy, where the fuzzy scheme outperforms than classical scheme. As the number of nodes increases there is drastic performance improvement in the fuzzy based Hello interval received packets while there is not much difference for the static value of hello interval as 1 and 1.5 sec, which can be realized from the **Figure 6.11(a)** and **Figure 6.11 (b).**





(a) for nodes=30 **(b) for nodes=40**

Figure 6.11: Average Received Packets V/S Pause Time

Summary

In this chapter fuzzy logic based optimization of reactive routing protocol AODV has been described. AODV uses the Hello messages to update the topology information and routing protocol in the wireless network. The frequency of the number of Hello messages affects the performance of the routing protocol. Instead of using static value of 1 sec standard for the hello interval which is the fixed interval between the hallo messages, proposed technique adaptively determines the hello interval by the Fuzzy Inference System. The performance of the Reactive routing protocol AODV has been evaluated in terms of changing the hello interval decided by fuzzy inference system with the AODV protocol which uses the standard static value of the hello interval of 1Sec and 1.5 Sec.