LOCALIZATION AND NODAL SECURITY IN WIRELESS SENSOR NETWORKS USING FUZZY LOGIC

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LOCALIZATION AND NODAL SECURITY IN WIRELESS SENSOR NETWORK USING FUZZY LOGIC

Amtur Rub

ABSTRACT

Wireless Sensor Networks are a group of nodes in randomly distributed pattern. In WSN the topology is arranged in random ways and ad hoc in nature. Distance estimation and security are the prime factors in WSN. The distances of nodes are calculated with respect to some known nodes. The node are of two types anchor nodes knowing their position in the system having GPS and sensor nodes whose distance are calculated with reference to the sensor nodes. Placing a GPS device in every node is not a feasible and cost efficient thing to do. Localization is the process to find the estimated location through coordinate system consisting of nodes. .

In this work to calculate the position of the sensor nodes using RSSI based localization method is used. In this we are taking two parameters of strength of RSSI signal and WEIGHT of node to calculate the DISTANCE of nodes. The RSSI signals are the preset values send by the anchor nodes to the sensor nodes. The WEIGHT of the node is provided using centroid method. The result is deduced in three phases: fuzzy matching, inference and combination of result. In fuzzy matching the conditions of the fuzzy rules are mapped, in inference rules are matched on the basis of their degree and in combination results are combined. Using MATLAB and the inference rules of fuzzy logic deduced we show that the higher the weight and greater the RSSI strength the distance is CLOSE TO THE ANCHOR NODE.

Security and trust of nodes is very essential in sensor network. Security of the data can be maintained using the cryptographic techniques. Much work has been done on this topic. Trust is an important issue in sensor network security. Trust is the parameter which one holds for other in each and every form covering the risk and incentives. Authenticating and authorizing were the two forms used earlier but today each node is checked for data packets send and received with addition to the earlier forms. Fuzzy logic is used to provide a wide range of trust values. The trust of these nodes is calculated using fuzzy rules to make a table of trustworthy nodes where each node is assigned its value of degree of trust.

A hypothetical model for nodal security is presented. The packets send and received are checked for the values each and every time of sending and receiving values in the reference table. If there is very large difference between them the node sending and receiving the packets cannot be trusted. The table is updated after every process. These values can be categorized in four groups of FRIEND, TRUST, DISTRUST and ENEMY. The friend and trust are in the safe zone whereas distrust and enemy are in unsafe zones for packet transfer. Every time the node is authenticated before sending or receiving the packets. If some node has fulfilled the criteria of trust five times it is automatically upgraded to the FRIEND level where authentication is done only once whereas if distrust is done for the five times it is degraded to ENEMY level. If ENEMY node sends the packets three times to wrong node it is discarded from sending or receiving packets.

Range free localization can be used for better and accurate results without any complication of hardware used for finding the node position in wireless sensor network. The proposed approaches are simulated using MATLAB. The results are compared with existing techniques through extensive simulations. The simulation results demonstrate the effectiveness of the proposed schemes in comparison to the previous methods.

Trust issues can be calculated and stored. The table can be made to store the data for future reference. The formulation of the trust model using fuzzy logic for the safe communication between source and destination node in wireless sensor network. Trustworthy of sensor node which participating the wireless network. If the sensor node has high trust value, other node can trust the sensor node and sending and receiving a data safely with it.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

List of Symbols and Abbreviations

WSN Wireless Sensor Network

GPS Global Positioning System

MEMS Micro electo mechanical system

RSSI Received Signal Strength Indicator

QOS Quality of service

TDOA Time Difference of Arrival

TOA Time of Arrival

RTOF Round Trip of Flight

POA Phase of Arrival

AOA Angle of Arrival

MDS Multidimensional Scaling

APS Ad-hoc Positioning System

$RSSI_{VVL}$ Very very low RSSI

$RSSI_{VVH}$ Very very high RSSI

VVL VERY VERY LOW

VVH VERY VERY HIGH

$WEIGHT_{VVH}$ Very very high weight

$WEIGHT_{VVL}$ Very very low weight

AVG Average

CHAPTER 1

INTRODUCTION

1.1 WIRELESS SENSOR NETWORK

In 21st century wireless sensor networks are important area of research consisting of wide variety of range from small burglars alarm to battle field surveillance. Today various tasks are completed using wireless sensor networks such as security, environmental monitoring, target tracking, air tracking, disaster relief and many more[1].

Wireless Sensor Networks work well in risk prone environment where large area is covered under the network having large and confident data to handle. Location of nodes can be found using localization as it is one of the basic problem when area is large and nodes are randomly deployed. For eg: in a forest if we need to measure the temperature and humidity for making a fire alarm the nodes will be present in random pattern. Calculation of exact position of the node is very important to deduce our result

Wireless Sensor Networks are a group of nodes in randomly distributed pattern. In WSN the topology is arranged in random ways and ad hoc in nature. Distance estimation and security are the prime factors in WSN. The distances of nodes are calculated with respect to some known nodes. The node are of two types anchor nodes knowing their position in the system having GPS and sensor nodes whose distance are calculated with reference to the sensor nodes. Placing a GPS device in every node is not a feasible and cost efficient thing to do. Localization is the process to find the estimated location through coordinate system consisting of nodes.

1.2 LOCALIZATION

Wireless Sensor Networks nowadays perform variety of work such as security, target tracking, home appliances, manufacturing of automobiles and so on. Sensor nodes are deployed in vast area having huge amount of data for storage. Nodes exact co-ordinate positions are needed for the whole system to work efficiently. Localization of the sensor nodes has become one of the major challenging issues in WSNs.

Increase in application of large number micro-electro-mechanical system(MEMS) in WSNs has lead to large interaction of systems. Nodes must compute and communicate with other network sensors properly and on time. The ad-hoc pattern of the network protocol leads to no prior protocol for communication. Node localization can be efficiently established for computing the position of nodes in coordinate system[63].

Location discovery is challenging issue in WSNs due to these four important reasons.

i. First to reduce the construction cost and nodal size hardware are used increasing the complexity of the system.
ii. Second if nodes are densely deployed the accurate position of nodes should be estimated to match the given topology which is difficult to achieve.
iii. Third nodes have very low transmission range so they are not directly in communication with anchor nodes increasing the problem.

iv. Last energy conservation is important for all tasks so each node follows minimum power usage policy.

1.3 SECURITY

Security and trust of nodes is very essential in sensor network. Security of the data can be maintained using the cryptographic techniques. Much work has been done on this topic. Trust is an important issue in sensor network security. Trust is the parameter which one holds for other in each and every form covering the risk and incentives. Authenticating and authorizing were the two forms used earlier but today each node is checked for data packets send and received with addition to the earlier forms. Fuzzy logic is used to provide a wide range of trust values. The trust of these nodes is calculated using fuzzy rules to make a table of trustworthy nodes where each node is assigned its value of degree of trust.

1.4 FUZZY LOGIC

In WSNs enhancement of decision making, reduction in resource consumption and increase in performances done through fuzzy logic[8]. Fuzzy logic allows intermediate values as it contains multi-valued logic which is appropriate instead of fixed or exact. The truth value of fuzzy logic ranges from 0 to 1.

Fuzzy logic was initially introduced by Lofti Zadeh the Mathematician in 1965. Many research fields are using the properties of fuzzy logic since then to enhance their work. Fuzzy logic models the conditions where the given solutions are neither true nor false but rather has a degree of correctness.

Fuzzy Inference System is the core part of the fuzzy reasoning process. The processes from giving input to deducing output consist of three parts:

i. Fuzzification
ii. Rule Base Evaluation
iii. Defuzzification

1.5 PROPOSED WORK

In our work to calculate the position of the sensor nodes using Received Signal Strength Information(RSSI) based localization method is used. In this we are taking two parameters of strength of RSSI signal and WEIGHT of node is used to find the DISTANCE of nodes. The RSSI signals are the preset values send by the anchor nodes to the sensor nodes and they do not require any addition hardware as it is inbuilt in physical layer of nodes. The WEIGHT of the node is provided using centroid method. The result is deduced in three phases: fuzzy matching, inference and combination of result. Using MATLAB and the inference rules of fuzzy logic which are deduced we show that the higher the weight and greater the RSSI strength the distance is CLOSE TO THE ANCHOR NODE.

A model for nodal security is presented. The packets send and received are checked for the values each and every time of sending and receiving values in the reference table. If there is very large difference between the nodes sending and receiving of the packets then such nodes cannot be trusted. The table is updated after every process. These values can be categorized in four groups of FRIEND, TRUST, DISTRUST and ENEMY. The friend and trust are in the safe zone whereas distrust and enemy are in unsafe zones for packet transfer. Every time the node is authenticated before sending or receiving the packets. If some node has fulfilled the criteria of trust five times it is automatically upgraded to the FRIEND level where authentication is done only once whereas if distrust is done for the five times it is degraded to ENEMY level. If ENEMY node sends the packets three times to wrong node it is discarded from sending or receiving packets.

CHAPTER 2

LITRATURE REVIEW

2.1Routing

Routing is used to reduce cost and time of sending data fron source to destination. Energy consumption and network life time are important.

Non-linear optimization is done in [4] using fair optimized routing protocol.Quality of data is monitored fuzzy theory for node energy consumption and increasing life time.

In [5] fuzzy membership function analyses cost in routing.Fuzzy multiobjective algorithm is used to maximize lifetime and energy consumption

Flexibility and ability to self-organize using cluster head switching is done in [6].Earliest-First tree (EF tree) and Source-Initiated Dissemination (SID) is used to classify data for using cluster head fuzzy method.

Selection of suitable neighboring node is done in [7] using fuzzy logic method. This enhances speed accuracy and power of routing. It uses real-time processing to enhance life time of network.

Multiple sensor nodes are routed in [8] to enhance energy usage. Fuzzy logic method is used for energy aware routing to enhance flexibility.

Multi hop routing is used to send data to sink node to reduce energy consumption in [9].Fuzzy Multi-hop routing (FUMOR) to enhance life time of network using cluster head.

In [10] working of GPS is done through fuzzy position based routing .Position vector is used to find node ID. Energy consumption and average delay decline due to clustering in this pattern.

Fuzzy C-mean Clustering (FCM) is used to detect abnormal flow in network. [11] Robustness and reliability is maintained by analyzing data flowing in the network.

LEACH (Low-Energy Adaptive Clustering Hierarchy) and FCM(Improving Life Time of Wireless Sensor Networks by Using Fuzzy c-means Induced Clustering) are used in [12]. Node enrgy and distance between center points are fixed through clusters. Multi-hoping is donein clustering.

In [13] Multi-Objective Fuzzy Decision Making (MOFDM) is used to choose the best solution from the given comprehensive comparisons of parameters as time latency, energy resources and reliability.

In order to calculate the minimum cost to determine shortest path the “fuzzy link cost processor” on FGPA is used.[14] is used to maximize the life span of sensor network. Spartran 3 is designed for a 50k gates.

[15] uses a fuzzy logic controller architecture to evaluate the capacity of each node's sending named data packets on self battery level. Controller is used for rejection or accepting of data packets. Energy efficient recovery is done using multipath between source and sink.

In [16] analysis and forwarding of important data is done through WSNs.

2,2 QoS

In [17] QoS architecture it has management and control module for node and sink level. Network dynamics are used to minimization of packet loss and maximization of traffic congestion is done using fuzzy logic and set variables.

The application layer and network layer are analyzed using fuzzy logic in [18]. Effectiveness is increased due to this comprehensive evolution model.

In [19] quantization of QoS index and weight. Fuzzy mathematics is used to enhance reality function of WSN.

2.3 CLUSTERING

For efficient coverage of network in [20] reclustering is done by fuzzy logic wherein sensing range and clustering parameters are defined. Prior knowledge about sensor location is not required.

LEACH and fuzzy logic based cluster head selection is done in [21]. Data stream and First Node Die (FND) reducing energy and distance.

Fuzzy position based routing clusters is used for searching without GPS support in [22]. Ambiguous position vectors reduce time and energy consumption which are avoided.

Fuzzy theory unequal clustering (FTUC) is used in [23] to extend lifetime for virtual blocks (VBs). Cluster routing tree decreases energy consumption.

Event detection, tracking and classification in WSN is done using event centric process in [24]. Two approaches double sliding window and fuzzy logic is used. Accuracy is maintained.

In [25] fuzzy logic system is made for detecting failure situation. Data accuracy, validity and usefulness to enhance optimal solution. Reliability is modified and improved for sensor reading.

Properties of sensor network database in [26] varies accordingly. Active database approach using fuzzy is applied to manage flexible and continuous queries. Data processing and management approach are required for reactive behavior.

WSNs are typically deployed in wide, unattended, and hostile areas. In [27] the compromization of physically and surreptitious node is evaluated. A dynamic en-route filtering scheme is proposed to detect and drop the fabricated data. Fuzzy key distribution authentication keys are redistributed to neighbor.

2.4 DECISION MAKING

In [28] Unified And-Or (UAO) is used to achieve trade off between attack detection and sensor node energy utilization rate. Markation is done using fuzzy logic to find the values of specific parameter used in attack detection scheme.

Multiple-objective fuzzy decision making (MOFDM) chooses the "best" path(s) in [29] to transmit the data. fuzzy decision making based information-aware routing protocol specifically for WSNs having cluster as a gateway node.

A 2-tier fuzzy system in [30] is used foe decision making mechanism. Selection of optimal protocol for application and performance is required. Fuzzy rule is used to produce the base.

In [31] the problem of cost, battery power and environmental problems are solved using localized decision making using fuzzy inference system. Power consumption is decreased due to decreased traffic rate and reliability is maintained.

Faulty reading nodes are removed using algorithm of average sensed value and fuzzy inference system. In [32] the computation complexity is low and accuracy is high.

2.5 DATA FUSION

In [33] event is detected using combination of parameters and fuzzy logic. Multiple sensor nodes provide additional information. Diverse sensors are collected at sensor head and fuzzy rule based method is applied to get maximum reliability and accuracy.

Inherent uncertainty make the decision unreliable. In [34] Statistical Process Control and a clustered covariance method using fuzzy logic and data fusion is implemented to reduce fault. This helps in decrease of false positive fault detection.

2.6 LOCALIZATION

To enhance the accuracy of location dependent system Sugeno-type fuzzy system is used in[37] to minimize the cost, maximize the system and make it simple by using collaborative localization algorithm.

The wireless sensor networks(WSNs) were evolved from micro-electromechanical systems (MEMS) and radio frequency(RF) technology. In [38] Probabilistic fuzzy logic based range free localization algorithm (PFRL) is applied for rescue and recovery in disaster.

Power durability and time utilization are the two important factors in localization technique used in wireless sensor networks. [39] uses a new fingerprint technique using radio frequency (RF) and fuzzy c-means (FCM) clustering in localization to tackle these problems. Received Signal Strength Indicator (RSSI) is used to find the position of nodes.

In [40] Fuzzy Logic Algorithm for Minimizing Errors (FLAME) is used to locate the accurate position of sensor nodes for localization techniques. To reduce the error rate groups of interacting sensors are used to locate the sensor node location.

In [41] adaptive neural-fuzzy inference system is used to provide information to fuzzy inference system. Distance measurement is done through T-R distance in Received Signal Strength Indicator (RSSI) using fuzzy system.

Calculating the exact position of sensor nodes is very important. [42] uses the Probabilistic fuzzy logic system (PFLS) for range localization. Received Signal Strength (RSS) is used as input for sensor node in this algorithm. PFLS is susceptible to environmental noise.

In [43] for improving flexibility and robustness in finding nodes position is done by implementing number of seeds in line-of-sight. Time of Arrival (ToA) and Angle of Arrival (AoA) are techniques for receiving information in form of periodically broadcasting from seed. Localization adjustment is done through adaptive fuzzy control.

Auto locating method is to find the position of sensor nodes spread in large area relatively with some reference nodes present in that network. It is done in [44] through localization based on Intelligent sensors (LIS) and it is used for vast area of wireless sensor network.

[45] uses ultra wideband(UWB) communication technology in Time of Arrival(ToA) to increase the range of the method. UWB is used for accuracy, confidentiality, high penetration and low power consumption. Time of direct signal is calculated by weighting coefficient using fuzzy logic technology.

In [46] to reduce complexity and optimize the system Fuzzy Support Vector Machine (FSVM) is used for device free localization. Fuzzy systems can be easily optimized after reducing the complexity of the fuzzy system. The correctness ratio of the system is increased.

The confusion caused by multipath and abnormal signal received is managed by [47]. Threshold value for RSS vector is calculated from a location fingerprint setup. Fuzzy clustering is done for locating nodes and Jffreys&Matusita formula is applied for finding the degree of similarity.

In [48] to reduce energy consumption and increase the accuracy of routing node location estimation was done. Seed nodes consisting GPS receiver are present which calculate the distance of other nodes. Using fuzzy logic the results are enhanced.

Fuzzy rules are used to track the sensor nodes while in motion. In [49] grid based map is used to define the position of mobile nodes and motion using sensor measurement nodes reducing the computation time. Fuzzy logic is proposed to calculate the global position estimation and local position tracking.

In [50] a Wireless Fidelity (WiFi) is integrated with Fuzzy Rule Based Classifier (FRBC) which is used for finding the position and Fuzzy Finite State machine (FFSM) that are needed for posture recognition. Any person carrying a device equipped with WiFi can be used to trace its location and human activity. It gives a robust, reliable and understandable system view.

Fuzzy optimization data fusion (FODF) is used in [51] enhancing the location accuracy of data in wireless sensor networks.

Neural network fuzzy is used for human localization in informationally structure space. A time series of neural network based data is used for learning method in [52].

In [53] for a range free localization a combination of genetic fuzzy and neuro fuzzy methods are applied. The input is taken as RSS signals from sensor nodes. Evolution and enhancement of localization algorithm is done at different noises.

2.7 TRUST:

Trust based secure localization (TBSL) is used to increase the accuracy by enhancing the trust value of beacon nodes by finding the identity and behavior of the nodes in [54]. Both external and internal nodes are secured by the help of this localization.

A trust assisted framework in hierarchical order is made for detection and localization of network anomalies in [55]. Bandwidth and efficiency are increased by making a mixed network structure. Accuracy and efficient two phase probing overhead are maintained by trustworthiness of network link.

[56] Uses the algorithm which reduces the need of trusted nodes for sensor nodes in localization. It works for few adjacent nodes so as to detect liar nodes by setting a threshold value and eliminating that comes below it.

Approximate point in triangulation test (APIT) algorithm used in [57] enhances the original algorithm by reducing the probability of in-to-out and out-to-in errors. The self positioning of some nodes is done by few localization schemes.

In [58] fast and up-to-date services for rapidly and frequently moving nodes are provided. The problem of less reachability is eliminated by this logistics in wireless sensor network.

Localization is used for flexibility and novel location aware application. In [59] a light RC4 in AT-Dist. Hop count information cannot be changed by providing a set of confidence index for all nodes. Malicious anchors are reduced hence reducing the threat of external attack.

In [60] secure computation is done through linear computation time in reference nodes. This work is helpful in defense mechanism as GPS and trust management cannot be applied to all nodes.

The verifiers and the provers are differentiated on the basis of location and the message exchange of the nodes. In [61] the timing uncertainties between sender and receiver are calculated to enhance the performance of the protocols. Uncertainty and error management were checked on SIMO with ToA as distance estimation value.

Trilateration based secure localization technique is used to find location and accuracy for beacon nodes having no trust model in [62]. The fading and liar tolerance level is adjusted according due to attack resistant technique.

2.8 OTHER RESEARCH

In [35] congestion is created when a malicious node is present. This problem is tackled by monitoring their respective neighboring node. A congestion index (CI) for each node is calculated and fuzzy index based logic is applied to find congestion degree. The packets are routed accordingly.

Equal clusters result in uneven load balance on the network. In [36] uneven clustering is done to balance the load in order to enhance features like energy loss, balancing resources.

CHAPTER 3

LOCALIZATION PROBLEM

IN

WIRELESS SENSOR NETWORK

3.1 WIRELESS SENSOR NETWORK

3.1.1 COMPONENTS OF WSNs

Wireless sensor network is a collection of unique nodes deployed in an ad-hoc format in a cooperative network. They are small, less expensive sensor nodes spread over a wide range in environment consisting of Microelectronic mechanical system(MEMS) and communication protocols. It is in the form of self organized nodes that can compute and communicate in their network wirelessly. The tiny nodes consist of three basic components: sensing the input data, processing that data and communication process for making the whole network.

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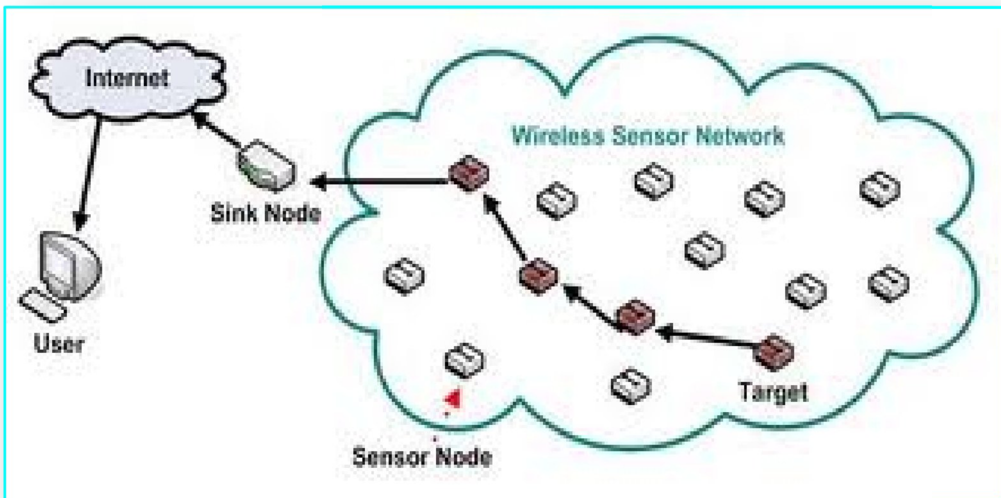

Figure 3.1: Wireless sensor network

i. Sensor Network: Area where sensor nodes are deployed in the geographical region. The node present in that areas have a specific process oriented task.

ii. Sensor Node: Node in WSNs is basic transmitting medium for data to travel from source to sink. They are of two types: first one is ANCHOR NODES having knowledge about their exact position and energy level and second one is UNKNOWN SENSOR NODES which do not have the knowledge about anything. Localization is used to find the unknown nodes with respect to anchor nodes.

iii. Target Node: Target Nodes are nodes which combine the parameters to deduce the result for sending to the destination node or sink node. Between target node and sink node there are many intermediate nodes.

iv. Sink Node: The node which is connected to the routing device to act as a gateway for sending the data to the specified location is known as sink node. Data is collected from sensor nodes to apply simple processing and send information to requested system.

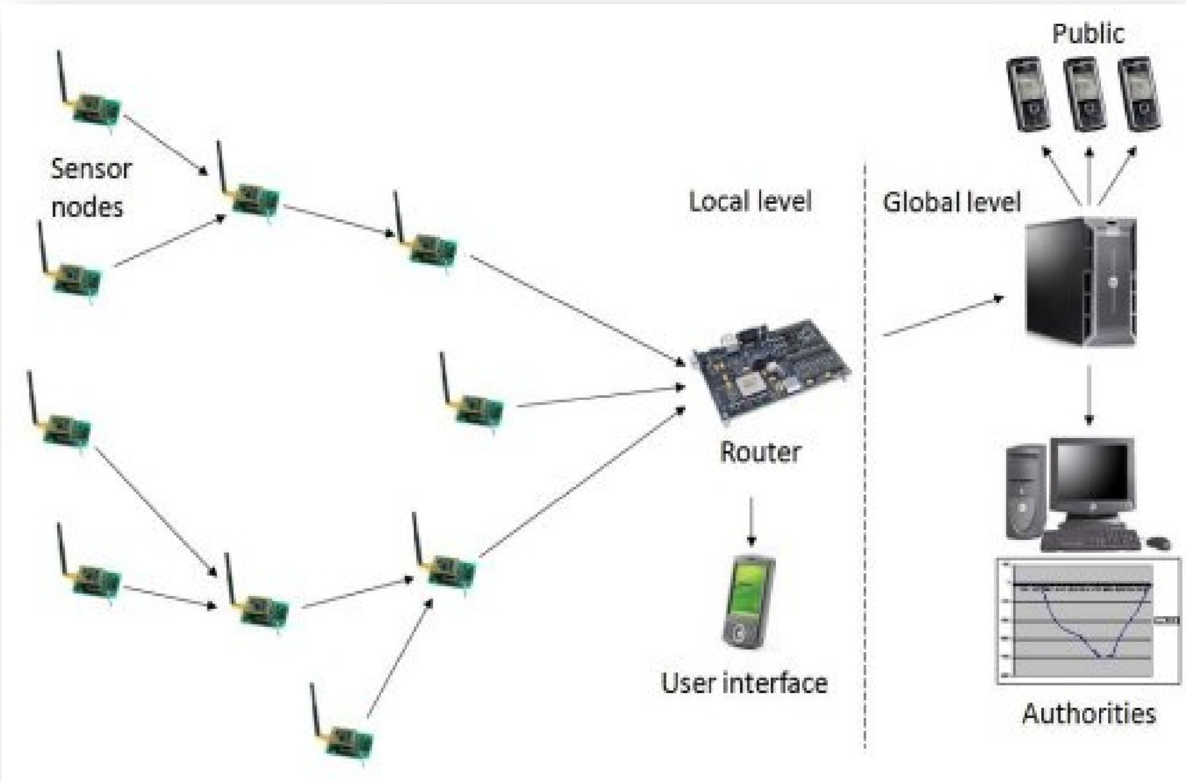

FIGURE 3.2: WSN

3.1.2 DESIGNING ISSUES IN WSNs

Every application in wireless sensor network has a specific requirement to be fulfilled. A common multi-purpose application is difficult to make as it may cause diversity resulting into a conflicting situation.

The design of WSNs can be broadly categorized into three parts:

i. Platform provided for nodes

ii. Protocols needed for communication
iii. Applications of the sensor nodes.

Designing factors are important as they serve as the points for algorithm and protocol design for the networks[63]. Networks capability and performance are influenced by the network design objective for individual application. The applications significance and impact of design selection are major factors for selection.

Main design objectives are as follows:

a) Less cost

Cost of nodes varies from application to application. It depends mostly on size and resources needed. Corrective maintenance and automated working makes sensor nodes easily deployed at rough environments but after completing the task or in case of node failure they cannot be used for future work. To reduce the overall cost of network cost of sensor node should be reduced.

b) Minimum size of node

Size of node can vary from small to large. Larger nodes cannot facilitate the proper working of the network due to increased resource consumption. Small size of nodes can enhance the deployment of nodes and decrease the cost and power utilization of the sensor network.

c) Low battery use in sensor nodes

Energy in nodes can be provides through mains power supply or batteries. Main supply is not a feasible approach as nodes are randomly deployed in different regions. Battery are not easily changeable or rechargeable there forth energy consumption should be low. To prolong the time span of whole network reduction of battery usage should be done.

d) Self configuration of the sensor nodes

Sensor nodes are placed in the volatile environment where everything is changing with a very fast pace. These nodes which are deployed in random pattern do not follow any specified protocol for arranging themselves instead they reconfigure as desired by the network at time of node failure or change in topology.

e) Adaptable and fault-tolerance:
WSNs are robust about the location of the nodes and failure of the nodes. Nodes can fail or move or join the new network area but without any change in network topology. Protocol in network design should be adaptive to topology and network changes.

f) Scalability of nodes

In wireless sensor network the nodes placement can vary from low density area to high density area according to the requirement of the application in a network. Scalability is very essential component in network design to increase the adaptability of the system. Scalability is defined as smooth working of a system despite of variation in the nodes present in the network.

Failures in nodes are common and can happen due to environmental problems, battery depletion or any other external issues. Tolerance in sensor nodes can be specified as capacity of nodes to test, calibrate, repair and recover themselves from any unwanted situation.

Other design issues include: deployment of multifunctional nodes, data processing and sensing capacity is very high, deployed in best way and nodes mobility.

3.1.3 CHALLENGES IN WSNs

- **i.** Energy capacity is limited
- **ii.** Network resource is less
- **iii.** Deployment in ad hoc format
- **iv.** Random distribution of nodes
- **v.** Environment is not fully reliable
- **vi.** Application is diversified

3.1.4 ARCHITECTURE AND DESIGN

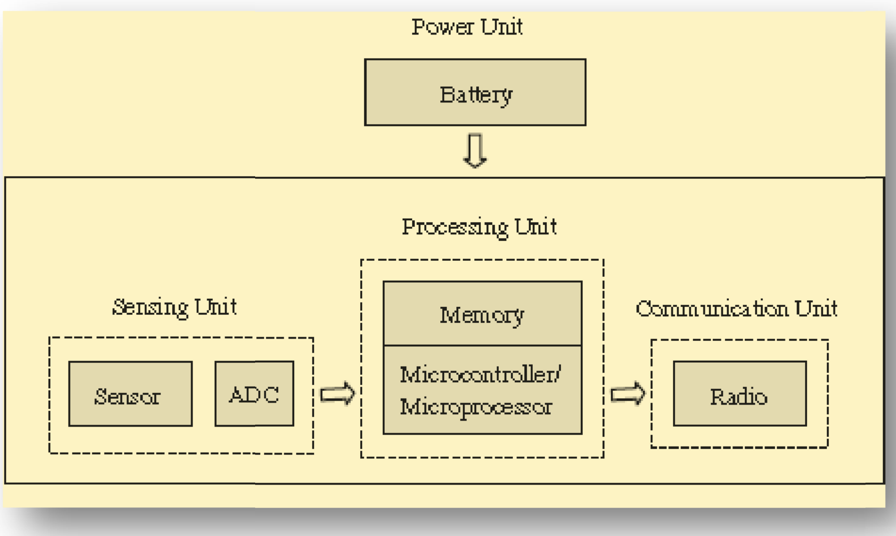

FIGURE 3.3: SENSOR NODE ARCHITECTURE[3]

Each node in WSNs has following components[1,2]

i. A SENSOR UNIT FOR SENSING: It is further divided into two subparts: having more than one sensor and one analog to digital converters(ADCs). The sensors produce analog signal when observing any phenomenon. These signals are then converted to digital signals from where they go to processing unit.

ii. A PROCESSING UNIT: To manage the assigned sensing work processing unit has a microprocessor and a storage unit for collaboration with other sensor nodes in easy way.

iii. THE COMMUNICATION PART: It consists of radio frequency transmitter and receiver having short range for communication between node and sensor network.

iv. POWER SOURCE: This is used to provide battery to all components of the senor node.

3.1.5 TYPES OF NODAL ARCHITECTURE

There are basically two type of nodal architecture:

i. ONE-HOP: Sending of data from source to sink is done through one hop routing. These types of routing become costly when distances are long.
ii. MULTI HOP: When distances are long then the whole network is divided into small nodal area communication is done through node to node transmission and then sends to sink. This reduces the energy consumption of whole network. They are further divided into two sub parts: Flat architecture
Hierarchical architecture

3.1.6 ATTACKS IN WSNs

Protection is important in WSNs when data is being transferred in the network. Attacks in WSNs are of two types[3]:

i. ACTIVE ATTACKS: Attacks in which data are modified or given false response come in the category of active attack. Active attacks can influence the resources. Modification can be defined as alteration of data, message reordering and tampering in routing of messages.
ii. PASSIVE ATTACKS: Resources are not affected in passive attacks. Information is obtained while message exchange between nodes is done. These types of attack are hard to detect as no message tampering is done.

3.2 LOCALIZATION

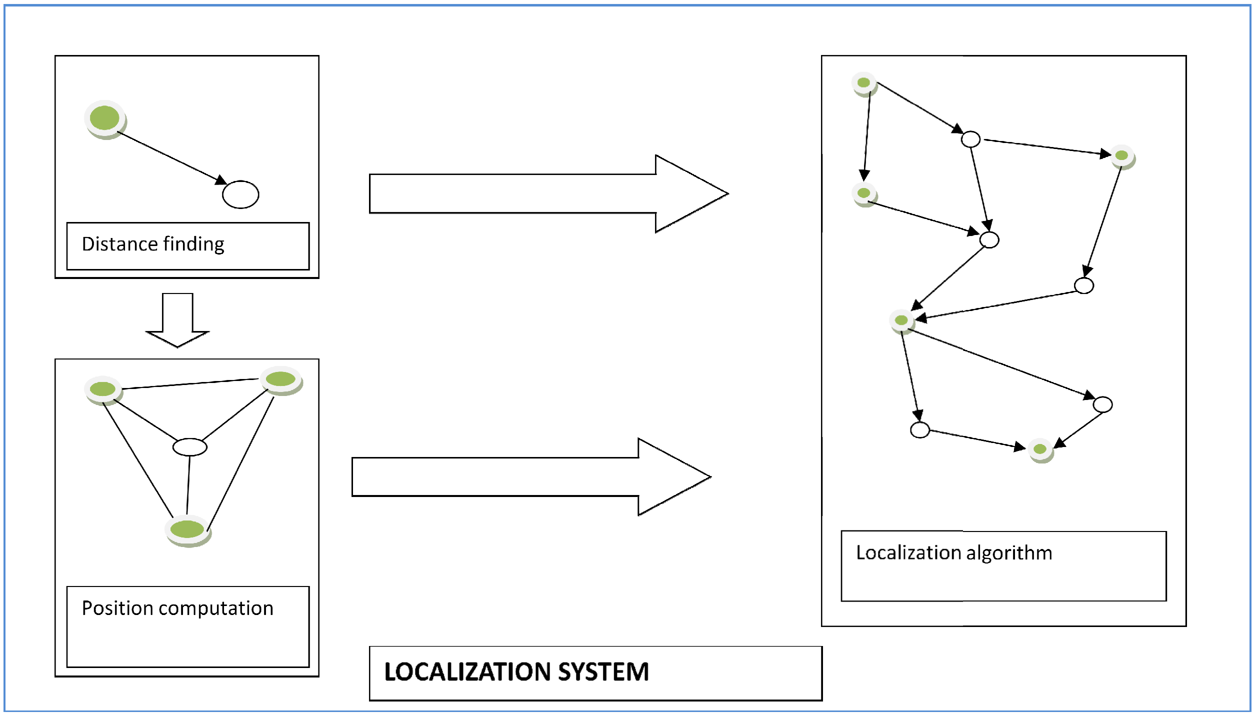

FIGURE 3.4: Localization System

3.2.1 LOCALIZATION SYSTEM

The localization system basically has two important parts:

a) Nodes Deployed
   Deployment of nodes is done in two ways. First nodes are placed in the known coordinates from where the initial information about them can be taken. Second Global Positioning System(GPS) is placed on every node. The nodes which are deployed consist of states ie, knowledge and management of its location during the process of localization. Nodes are of three states:
   i. Anchor nodes which know their position in the coordinate system by deploying manually or through GPS.
   ii. Unknown nodes are target nodes having no information about their position in the geographic area.
   iii. Settled nodes are unknown nodes which after some times can estimate their position with respect to the anchor nodes.

b) Localization algorithm
   This algorithm is applied for finding the position of the nodes which do not know their geographical position. According to the need of application many ways are defined to calculate the location. For example: GPS technique. The localization of nodes is done by sensing the node with respect to anchor nodes and communicating in wireless pattern for

the better result. The wireless communication includes RSSI method, TDoA method, triangulation method and many more.

3.2.2 ADVANTAGES OVER GPS

Due to the following reasons adding GPS connection to all the sensor nodes is not a feasible method:

i. Hard to implement GPS system where line of sight is blocked for communication purpose.
ii. Life of whole network is reduced as the battery consumption is increased by GPS system.
iii. With the increase in the number of nodes the production cost of system increases resulting in a big problem.
iv. The basic requirement of keeping the size of sensor nodes small is violated as adding GPS system to each node increases the size considerably.
v. The efficiency of the system is gradually decreased.

3.2.3 IMPORTANCE OF LOCALIZATION

Localization becomes important and key technology in WSNs for operation and development due to following reasons[64]:

i. Events origin
ii. Sensors Group Query
iii. Protocols to route the data
iv. Network coverage
v. Gathering data for identification and correlation
vi. Addressing the node
vii. Management and query of sensor nodes
viii. Nodes evaluation
ix. Generation of the energy map
x. Coverage of the network
xi. Routing in rough geographical area
xii. Tracking of objects(static or moving)
xiii. Energy efficient protocols for routing

3.2.4 LOCALIZATION TECHNIQUE

Localization is the process of finding the position of the nodes. The techniques can be broadly divided into two parts:

RANGE BASED LOCALIZATION TECHNIQUE

RANGE FREE LOCALIZATION TECHNIQUE

3.2.4.1 RANGE-BASED TECHNIQUE

In Range-based localization protocols are used to measure the exact distance of hop to its next hop or angle at which signal strength fall on a specific location. This localization technique is more costly due to use of hardware but the accuracy is increased. Range based localization techniques are further divides into four parts.

i. Received Signal Strength Indicator(RSSI)

The distance between anchor node and unknown node is calculated by mapping distance with RSS. As the distance increases the signal strength decreases for the transceivers due to path loss while propagation of signal. The path loss can be defined as loss in signal strength due to environmental conditions and is inversely related to RSS signal.

$$\text{PATH LOSS} = 1/\ \text{DISTANCE}^{\text{PATH LOSS VALUE}}$$

The path loss value is different for different environment in a wireless sensor network.

RSSI is unreliable as signal propagation is effected by many physical hindrances which cause scattering, diffraction, refraction and reflection resulting in weaker signal strength and more errors.

There are two ways for mapping distance in RSSI method:

Analytical Mapping Methods are used to simulate the distance and RSS by using a mathematical formula. The mapping of data is tough and complex task.

Limitation of analytical method include environmental depended values are used and accuracy is low.

Empirical Mapping Methods are used to map data in localization process. This is done in two phases: In first phase include gathering of RSS in specific location and then forming a map of location and measured signal. In second phase comparisons between the mapped values are done and the value closest to it is selected. The accuracy results are higher than analytical method.

Limitation of empirical method include very accurate profiling of environment should be done, offline calculation is very huge and is mostly non reliable in changing scenario.

ii. Time Based Localization Approach

Time based localization uses propagation of radio signal from sending node to receiving node to calculate the distance between them. There are three ways to calculate time based approach:

Time-of-Arrival(TOA) is the method to calculate the distance by sending or receiving the radio signal between the simultaneously paired nodes. The time is calculated by subtracting the received time from the send time with a multiplication factor of RF signal.

There are a few limitation of using TOA method which includes accurate synchronization of nodes, RF bandwidth size, logging in path and clock arrangement.

Round-trip of Flight(RTOF) is used for measuring the time of receiving data back to the sender node. This is done to eliminate the problem of synchronization in system clock as same clock is used to measure delay and error in the signal processing. The distance is calculated by multiplying the RF signal to the time difference between sending and receiving the signal. The result is divided by 2 to find the distance between nodes.

The limitation of RTOF includes accuracy reduced due to noise, non line of sight path cause signal unavailability.

Time Difference of Arrival(TDoA) is used to map the location of two different receiver nodes having different geographical area from a single sender node. The distance is calculated by initially finding the products of both the RF signals and time difference of receiving. The product is then divided by difference of RF signals. It provides better accuracy then other two techniques.

The limitations of TDoA are providing hardware with different transceivers increases the cost and can be best used only in low power devices.

iii. Angular-based Localization Approach

The Angular-based localization uses the angle for computing the distance between anchor node and unknown node in a specific direction. If the angle is unknown then two anchor nodes send signals to define the angle by connecting to the unknown nodes.

The orientation of node is defined as its reference to the direction of angle formation. It can be of two types: absolute or relative. In former the direction should be north having an angle of 0^o. in latter form direction is deduced using reference of absolute node.

Orientation plays very important role in finding the position of unknown nodes with respect to anchor nodes. When known we need only two anchor nodes else if unknown three non collinear nodes are needed.

Few advantages of using AoA techniques include: It increases the robustness as distance can be estimated and noise can be reduced and no time synchronization is required.

The limitations of this localization technique include: high power devices are used hence increasing the cost, complex computation and environmental challenges.

iv. Phase-based Localization Approach

The phase based localization is used when the wavelength of signal has longer wavelength as compared to distance estimated. Carrier phase of received signal strength is found to calculate the distance. Sinusoidal waves are sent to deduce the result. It improves the accuracy.

The limitation of PoA includes line of sight, estimation is tricky

3.2.4.2 RANGE-FREE TECHNIQUE

In range-free technique no prior assumption is made about availability of nodes in the specified area. In this localization technique no prior knowledge of distance or angle estimation is required. This localization technique does not require any extra hardware for its implementation thus reducing the cost of whole system. This provides accuracy in finding the exact position of the node. These techniques can be classified into two parts:

i. **Anchor-based Localization Approach**

Target nodes calculate their positions on the basis of existing anchor nodes. The anchor nodes know their position and number of anchor nodes used depend on the dimension of target nodes.

There are basically three ways for calculating the area based technique:

Area-based techniques apply polygon rule to find the position of unknown node. The radio signals are send for target location. There are two methods implemented are:

Centroid method: Geometric center of the location point is calculated using centroid point. It provides accuracy and easy computation.

Approximate Point in triangle method: The location of unknown nodes is calculated by forming the triangle of known nodes and then finding the coordinates of the triangle in which the unknown node falls. Triangles are combined and tested. Basic challenge is finding the location of

Global Optimization uses global information about sensor nodes. The optimal solution is found for the problem using Multidimensional Scaling(MDS). Differences between data are compared for better result.

Multi-hop approach uses as many necessary hops as required by the unknown node. Ad Hoc Positioning System(APS) is one of the example of multi hop system. The shortest path of anchor nodes are identified.

ii. **Anchor-free Localization Approach**

Event driven methods exploit properties of temporary need to the event. It can be signals of any form. It leads to accuracy.

3.2.5 LOCALIZATION ALGORITHM

Localization algorithm can be categorized in two parts:

CENTRALIZED ALGORITHM

DISTRIBUTED ALGORITHM

The algorithms are compared in the following table:

TABLE 2.1 COMPARISION BETWEEN LOCALIZATION ALGORITHMS

EVALUATION POINTS	CENTRALIZED	DISTRIBUTED
Calculation area	One main node	Any single node
Source of calculation	All nodes	By neighboring nodes
Exactness of node calculation	More	Less
Flexibility	Less	More
Battery use	More	Less
Delay in work	More	Less
Backup for processing	Not provided	Provided
Topology used	Pre defined	Random

CHAPTER 4

FUZZY LOGIC

4.1 INTRODUCTION

In WSNs enhancement of decision making, reduction in resource consumption and increase in performances done through fuzzy logic[8]. Fuzzy logic allows intermediate values as it contains multi-valued logic which is appropriate instead of fixed or exact. The truth value of fuzzy logic ranges from 0 to 1.

Fuzzy logic was initially introduced by Lofti Zadeh the Mathematician in 1965. Many research fields are using the properties of fuzzy logic since then to enhance their work. Fuzzy logic models the conditions where the given solutions are neither true nor false but rather has a degree of correctness.

Fuzzy Inference System is the core part of the fuzzy reasoning process. The processes from giving input to deducing output consist of three parts:

i. Fuzzification
ii. Rule Base Evaluation
iii. Defuzzification

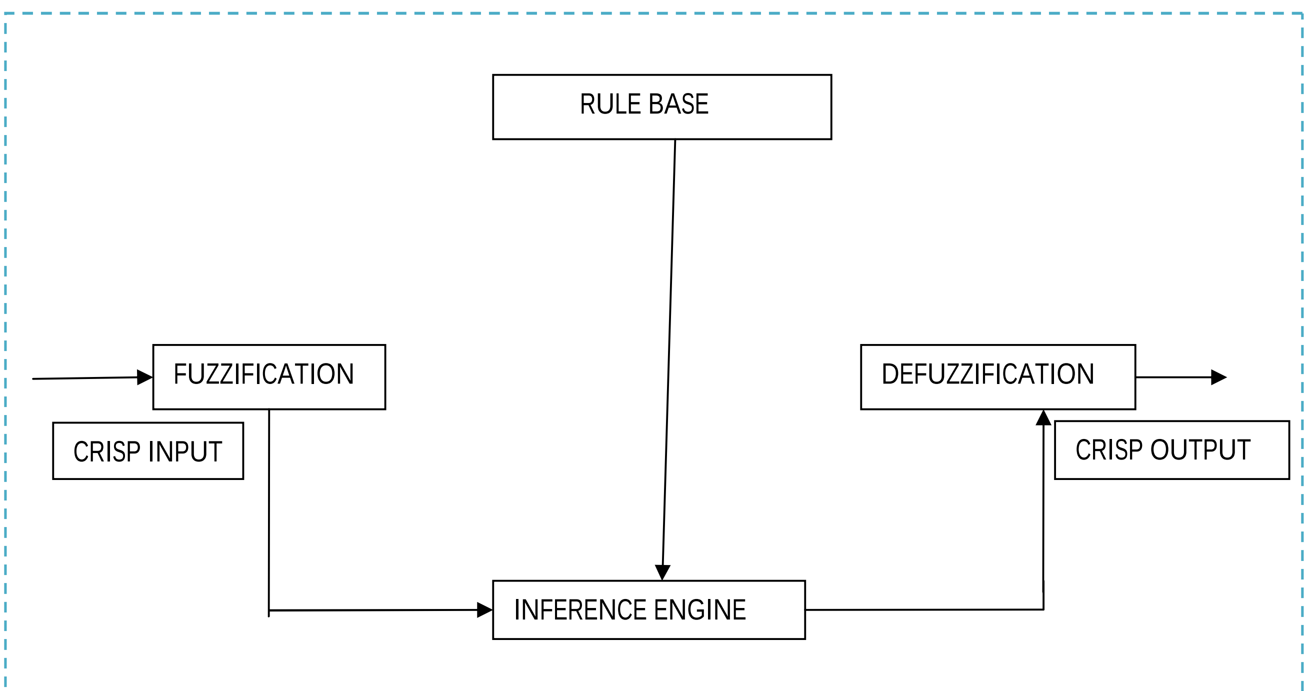

Figure 4.1: Fuzzy Logic Architecture

Fuzzy logic is different from old multi-valued system in substance and concept. Fuzzy logic works as human mind deducing the result as soft computing. Soft computing has few advantages over hard computing:

i. Precision tolerance is exploited
ii. Robustness by providing partial truth
iii. Easily tractable
iv. Solution is given in low cost

Fuzzy logic focuses on the output or solution to the problem of the system rather than the internal architecture or mathematical model of the system. The trade-off between significance and exactness is maintained in fuzzy logic.

When there is a proper link between components of set theory and prepositional logic they work in identically same manner. In proposition statement are defined which are having the terms. In past days the data applied to propositional logic was meaningful giving the outcome as either "true" or "false" but by using logical reasoning we can combine the propositional logic with other propositional logic many times to deduce our desired result.
Proposition have three fundamental rules for the combination of the values:
Conjunction: The and(^) operator is used to combine the values
Disjunction: The or(v) operator is used to combine the values
Implication: The $\rightarrow$ operator is used to imply that first value initiates the second value.

For example: "Rain is very low this year."
Rules that can be deduced through this sentence are:

IF the rain is very low,
THEN the crops grow less this year

4.2 FUZZY INFERENCE SYSTEM

All values in fuzzy system are entered in form of crisp values and output is also received in crisp format. Crisp or singleton values are the values which can be defined and measured by sensor nodes and send to system for processing whereas in fuzzy system the values are unclear and have different interpretation for different values[65]. Linguistic variables are variables which have values as word or sentences but not the numbers are taken for input. Fuzzy inference system can be broadly categorized into four parts fuzzification, defuzzification, knowledge base and inference engine which are explained below.

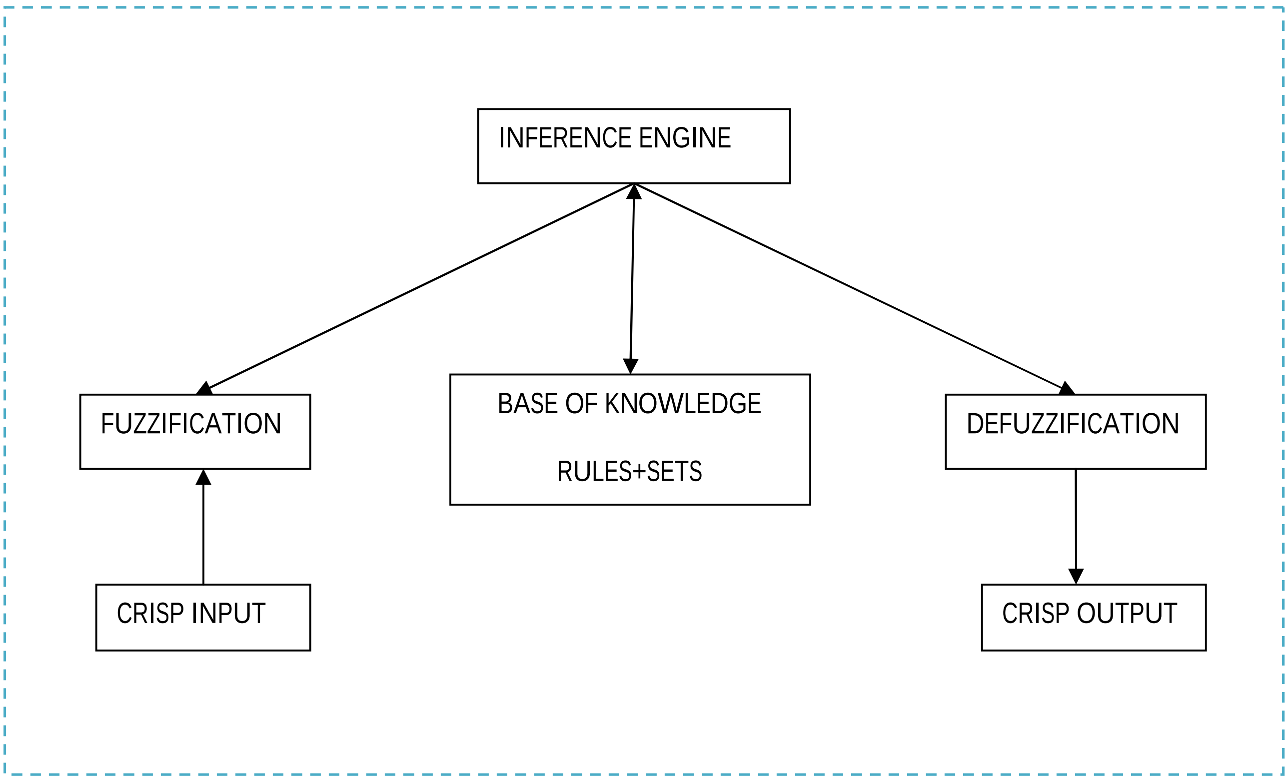

Figure 4.2: Fuzzy Inference System

4.2.1 FUZZIFICATION

The initial process of fuzzy inference system is fuzzification. Converting the input values to its respective output values using membership function for fuzzy variable is called fuzzification. To deduce result more than one rule is necessary. The lookup table or function evolution is used to show the input of fuzzification. Fuzzifier changes the input values (crisp) to fuzzy input using domain transformation function. Input variables can have many fuzzy sets. In fuzzy inference unit membership function is defined for every crisp unit.

The main components of fuzzification process are further explained using the following diagram. The membership function defines the degree at which any crisp value has its domain in the fuzzy set.

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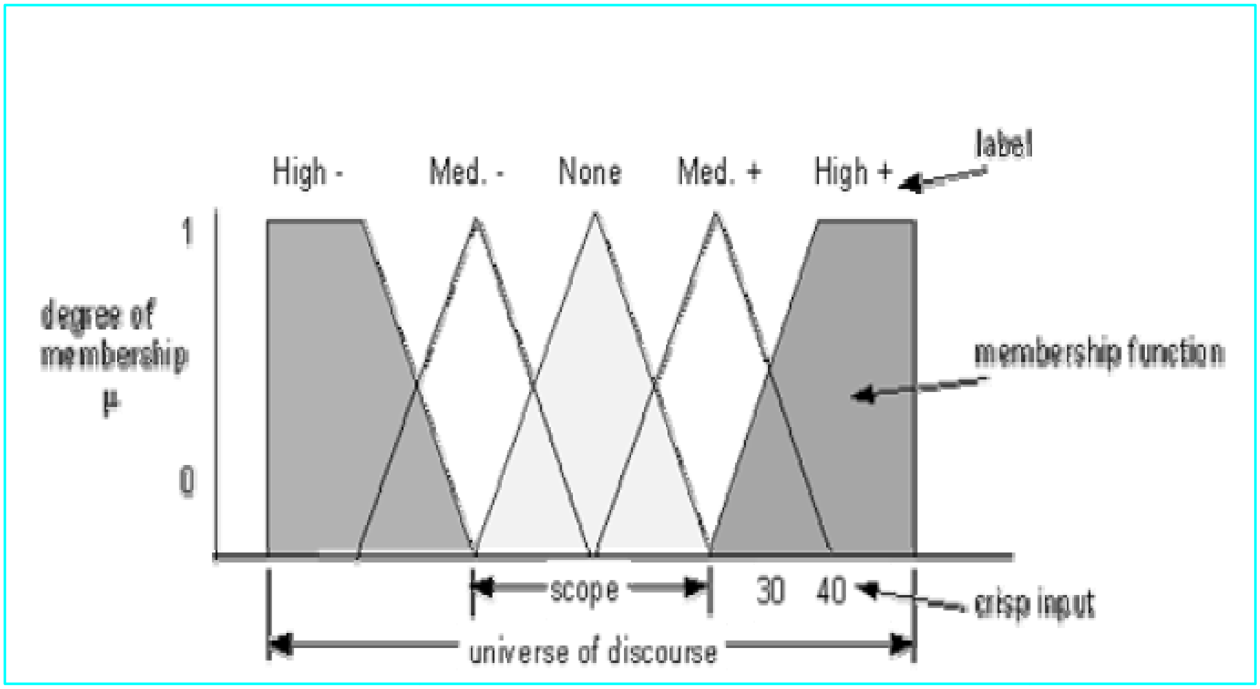

Figure 4.3 Membership Function[65]

i. MEMBERSHIP DEGREE**:** It is known as fuzzy input. It can be defined as degree of compatible range of crisp value to membership function, called as truth value and ranges from 0 to 1.

ii. MEMBERSHIP FUNCTION: It is defined as mapping of crisp values domains to membership degree of the region.

iii. CRISP INPUT: Inputs present from system variable from external parameters of control system. For eg: 30 marks.

iv. LABEL: Names given to distinguish a membership function.

v. SCOPE: Range mostly numbers are where mapping of membership function is done. Domain is the width of membership function.

vi. UNIVERSE OF DISCOURSE: All possible values having variables of the system.

There are many shapes in membership function such as triangular, trapezoidal and Gaussian by the knowledge of domain or via learning techniques application.

4.2.2 KNOWLEDGE BASE

Knowledge Base consists of two parts fuzzy set and fuzzy rules.

FUZZY SET: The fuzzy set is a set of values used in a controlled way to find the member values of fuzzy logic. In the set each value has its own membership degree ranging from 1 to 0 having maximum to minimum degrees respectively.

FUZZY RULES: The rules in fuzzy are applied in if……… then………… format. The **if** operator consist of fuzzy input variables and its equivalent input values. The **then** operator deduces the result by checking the operator and inference used. The three operators used in fuzzy logic are:
AND operator: finds the minimum of given set of values
OR operator: finds the maximum of given set of values
NOT operator: finds the negation of the given values

4.2.3 INFERENCE ENGINE

Inference engine is used to deduce the result in fuzzified format. The engine takes the value from the input variables and knowledge base system to find the result.

4.2.4 DEFUZZIFICATION

The process of converting a fuzzy output to crisp output is called as defuzzification. The result is calculating using to centroid of the given sets. The defuzzification process can be computed in many ways:
Center of Gravity method: the shapes obtained by output rules are formed by imposing the centroid shape to deduce the result. The output is marked in one coordinate of centroid.

Maximum output method is used to find the output by combining the maximum values of membership function. The output values are determined by activity having maximum value.

4.3 TYPES OF FUZZY SYSTEM

Fuzzy inference system can be classified into two parts

4.3.1 MAMDANI TYPE FUZZY SYSTEM

In mamdani type fuzzy system there are sets of fuzzy inputs, fuzzy rules and fuzzy output variable whose values need to be calculated using defuzzification. There is a set of output values deduced.

4.3.2 SUGENO TYPE FUZZY SYSTEM

In sugeno type fuzzy system the input and rules of the fuzzy logic remain the same only the output function changes. The output of sugeno is a singleton value corresponding to the given input values.

There are few differences between these two fuzzy methods which are tabled below:

TABLE 4.1: DIFFERENCE BETWEEN MAMDANI AND SUGENO FUZZY

	MAMDANI TYPE FUZZY	SUGENO TYPE FUZZY
i.	Intuitive and human like approach	Constant values are used
ii.	More Computational work can be done	More Computation work can be done
iii.	Fuzzyfied output is generated	Crisp output computed by Weighted average
iv.	Interpretability and expressing power is more	Interpretability and expressing power is lost
v.	More processing time required	Processing time is reduced as crisp output is generated
vi.	Defuzzification is time consuming	No defuzzification is required
vii.	Used in decision support application	Used where optimization is required
viii.	Output membership function present	No membership function present
ix.	Flexibility in system design is low	Flexibility is high as it can be integrated with ANFIS

4.4 LIMITATIONS

i. Memory is consumed in sorting the specified rule.
ii. Exponential increase in rule with respect to increasing variable.
iii. Heavy rule base slows downs the system.

CHAPTER 5

RESULT AND ANALYSIS

5.1 OVERVIEW OF TOPIC

Wireless Sensor Network has many sensor nodes in network area. The nodes are of two types; anchor nodes which know their position in network and sensor nodes which are not aware about their position. Let us assume that there are m anchor nodes in sensor network having their parameters as $(X_1,Y_1),(X_2,Y_2),\ldots\ldots..(X_m,Y_m)$. Beacon signals are periodically send by anchor nodes having information about position. The sensor node receives the RSSI send by adjacent anchor nodes to find its position in the sensor network.

The weight is computed with the help of RSSI values send by the anchor nodes to sensor nodes. It is done using centroid method which is an area based localization technique and works on the principal of radio connectivity in anchor and sensor nodes. The location is estimated as a centroid point for sensor node having anchor node around it.

To reduce cost and increase accuracy range free localization techniques are used instead of range based techniques. In range free technique no specific hardware is required for distance calculation as it is inbuilt in physical layer of sensor node.

Using Received Signal Strength Indicator(RSSI) distance between anchor node and sensor node is calculated Localization of wireless sensor network is done by using mamdani and sugeno type fuzzy methods.

5.2 IMPLEMENTATION AND RESULT

The implementation is done in both fuzzy systems to deduce the result. Here the figures are shown for input and output values in fuzzy system.

5.2.1 MAMDANI FUZZY SYSTEM

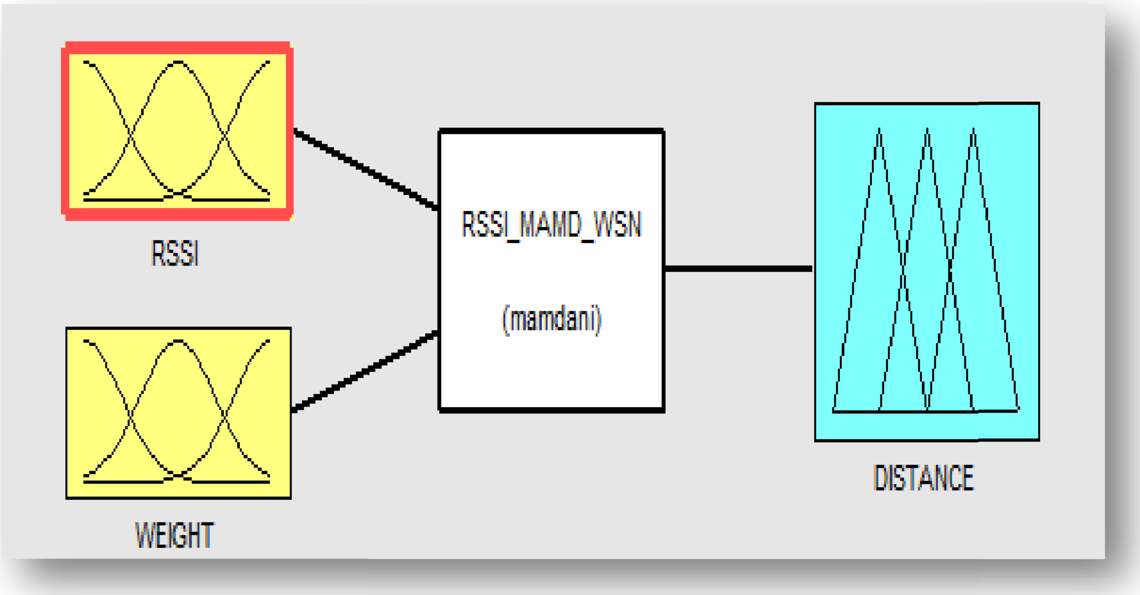

FIGURE 5.1 MAMDANI-TYPE FUZZY SYSTEM

5.2.1.1 INPUT VARIABLES

The input values are RSSI received from anchor nodes and weight of the sensor nodes. The fuzzy rules are deduced and set of functions are made. The output is in form of fuzzy set which is then needed to be defuzzified.

The range input membership function of RSSI is from [$RSSI_{VVL,}$ $RSSI_{VVH}$] where $RSSI_{VVL}$ denotes the least value of signal strength and $RSSI_{VVH}$ denotes the maximum value of signal strength. The membership function of RSSI are divided into 9 triangular membership function ranging from very very low(VVL) to very very high(VVH).

The weight of the node is calculated using the centroid localization technique. The sensor nodes deduce their distance from anchor nodes. If three or more anchor nodes are present then the sensor node is taken as the centroid if the polygon and its weights are calculated.

The range of weight is also kept same as of RSSI having 9 membership function ranging from very very low(VVL) to very very high(VVH). The input membership function of weight is from [$WEIGHT_{VVL,}$$WEIGHT_{VVH}$] where $WEIGHT_{VVL}$ denotes the least value of weight and $WEIGHT_{VVH}$ denotes the maximum value of weight.

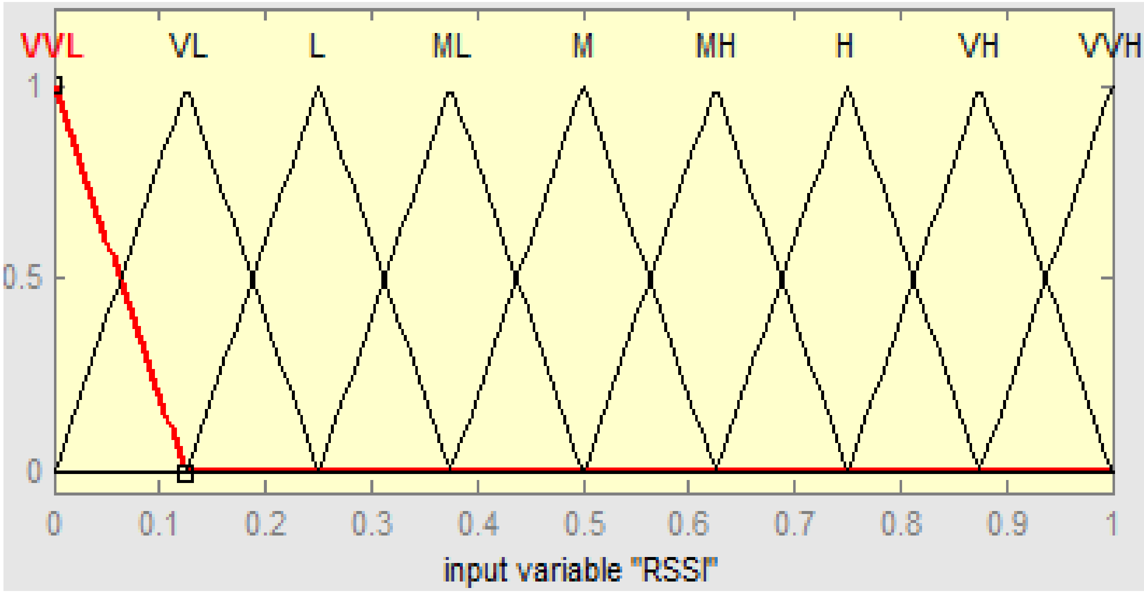

FIGURE 5.2 RSSI INPUT

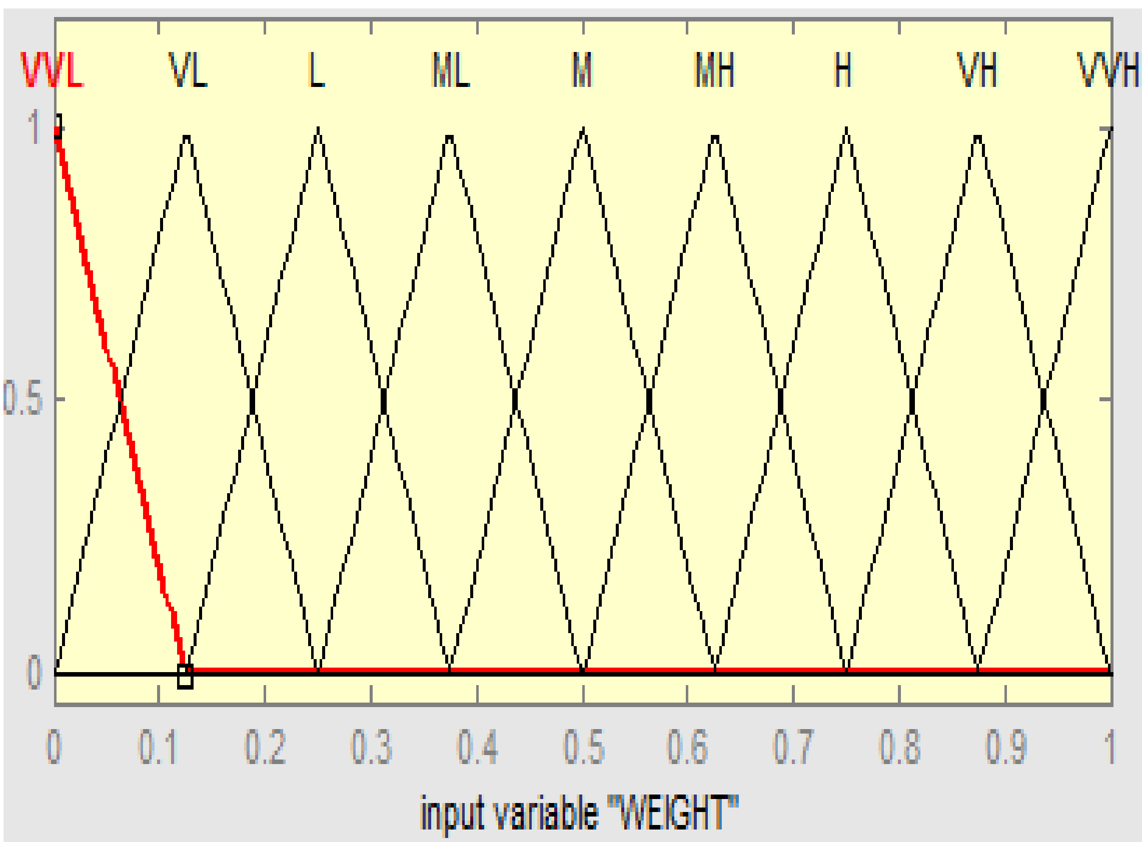

FIGURE 5.3 WEIGHT INPUT

5.2.1.2 INFERENCE RULES

The inference rules of the membership function are deduced to get the output distance. The rules are in terms of strength of RSSI and WEIGHT.

TABLE 5.2: RULES

RULES	IF RSSI IS	OR WEIGHT IS	THEN DISTANCE
1.	Very Very Low	Very Very Low	Very Very Far
2.	Very Low	Very Low	Very Far
3.	Low	Low	Far
4.	Medium Low	Medium Low	Medium Far
5.	Medium	Medium	Medium
6.	Medium High	Medium High	Medium Close
7.	High	High	Close
8.	Very High	Very High	Very Close
9.	Very Very High	Very Very High	Very Very Close

The output membership function of distance is given as:

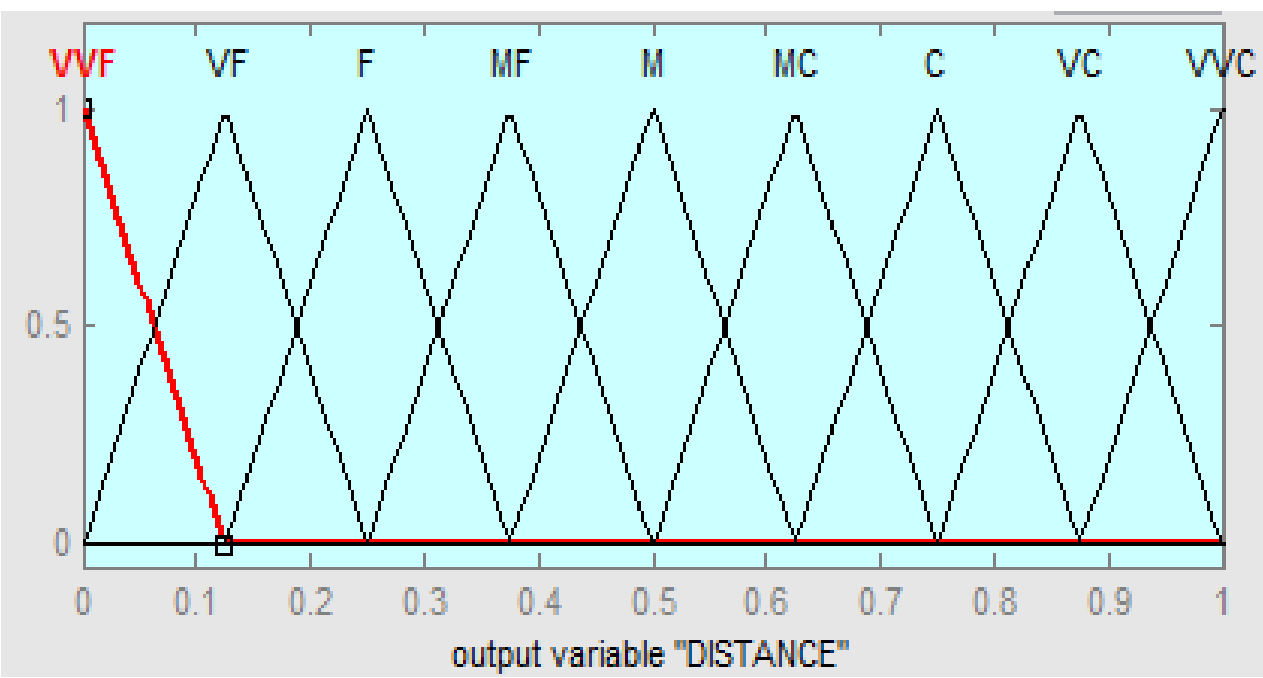

FIGURE 5.4 DISTANCE FUNCTION

5.2.1.3 OUTPUT

The outputs of the RSS strength and WEIGHT on sensor nodes calculated at 3 different points are given below:

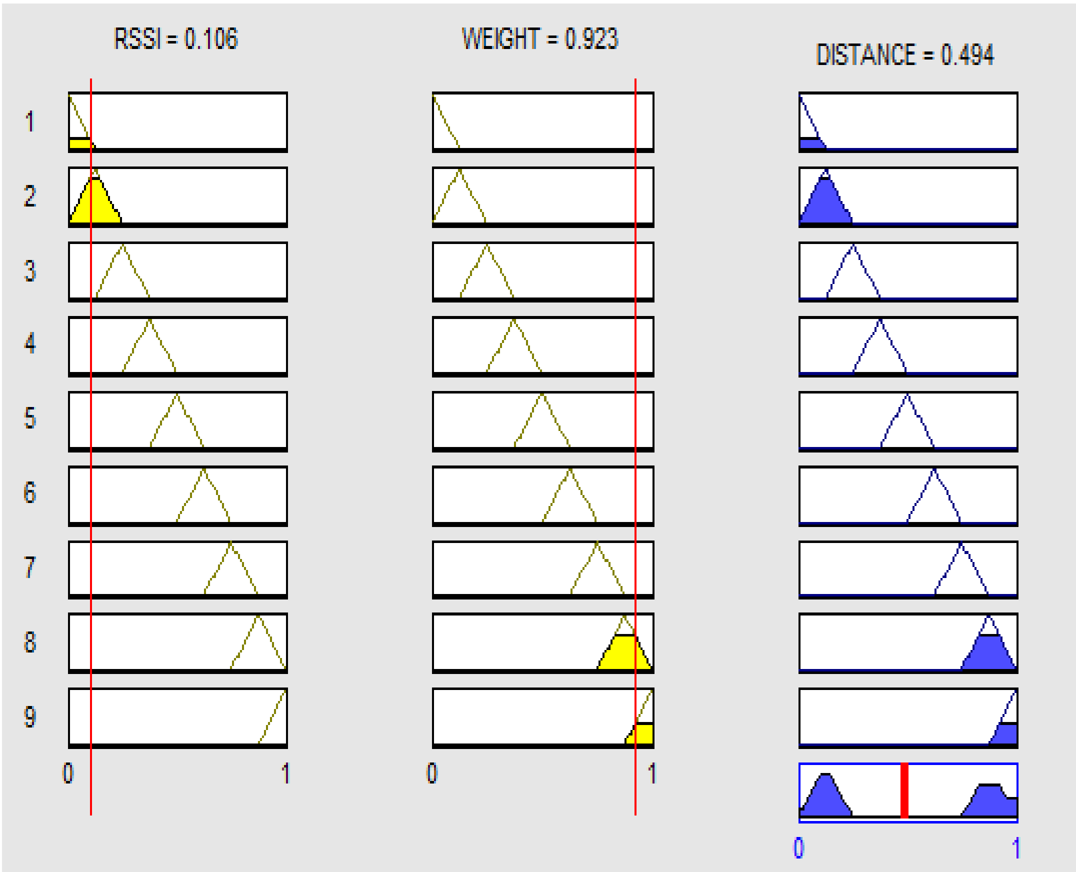

FIGURE 5.5: OUTPUT VALUES OF DISTANCE

Here the signal strength is taken as 0.106 and weight is taken as 0.923. The output 0.494 is distance from anchor nodes.

Similarly the other inputs: distance is 0.5 and weight is 0.505
And distance is 0.188 and weight is 0.868

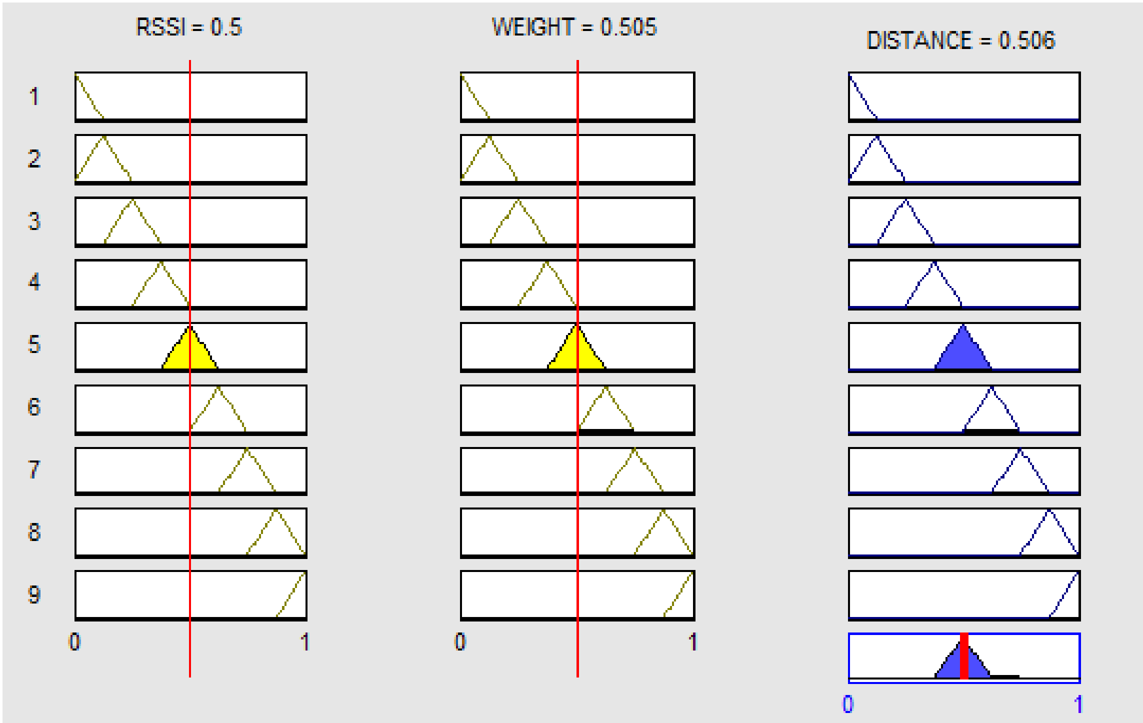

FIGURE 5.6: OUTPUT VALUE 1

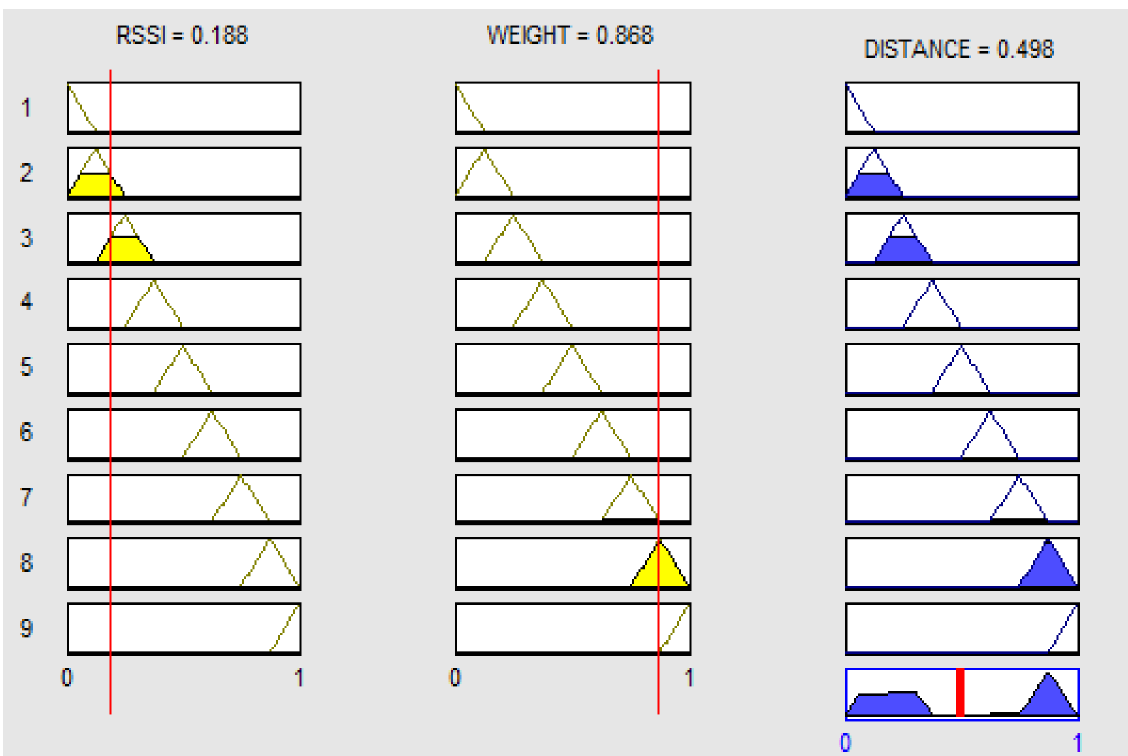

FIGURE 5.7: OUTPUT VALUE 2

The surface view of the function is seen as:

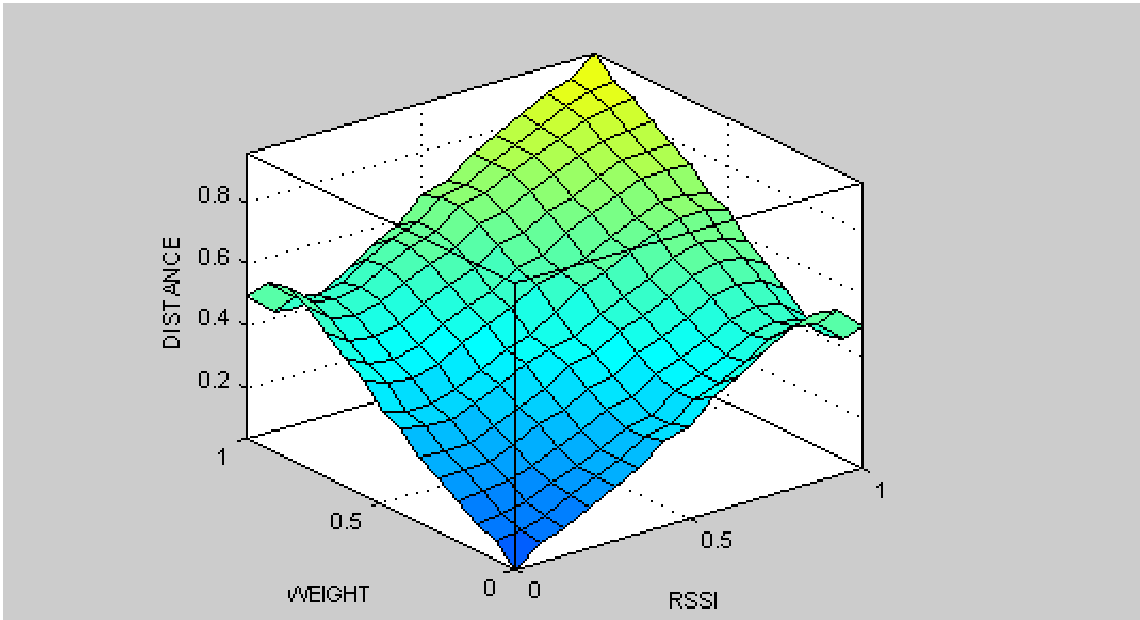

FIGURE 5.8: SURFACE VIEW OF OUTPUT

5.2.2 SUGENO FUZZY SYSTEM

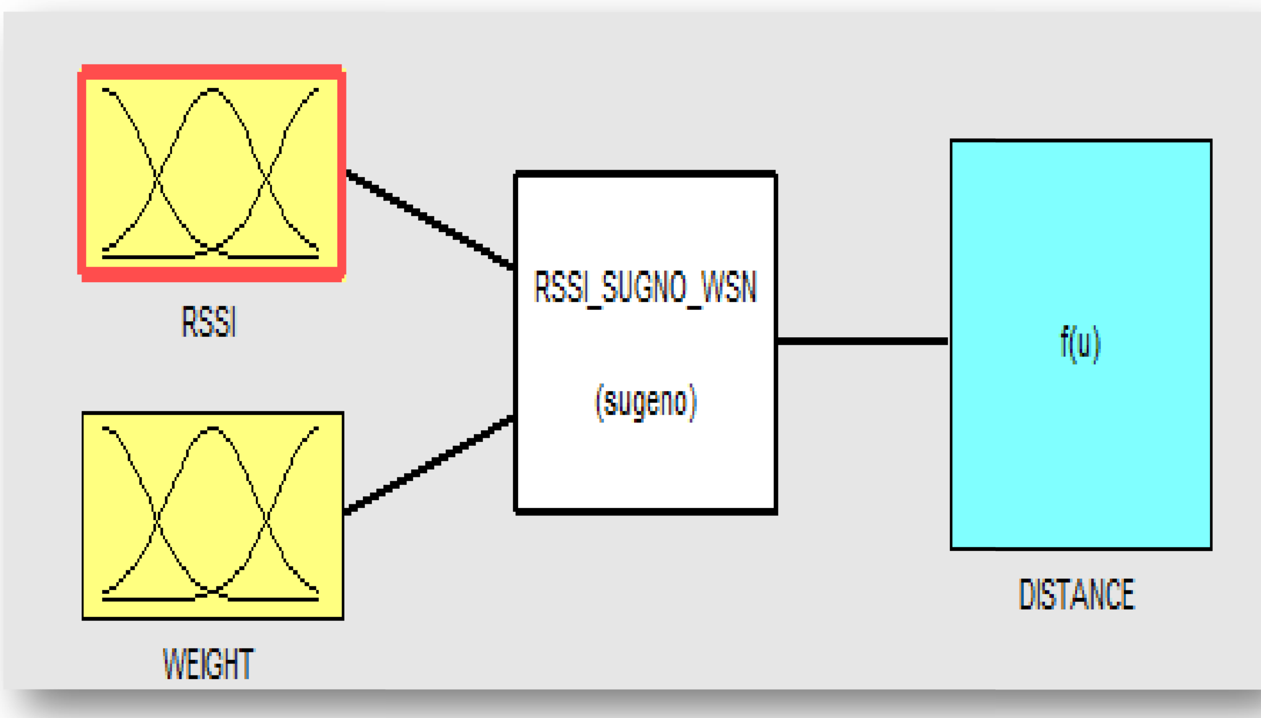

FIGURE 5.9: SUGENO-TYPE FUZZY SYSTEM

5.2.2.1 INPUT VARIABLES

There is no difference in input values of both the systems. Hence the values of RSSI and WEIGHT are kept same having same number of membership functions.

5.2.2.2 INFERENCE RULES

The inference rules of sugeno fuzzy system are same as mamdani fuzzy system. Then we have same 9 rules for deducing the output.

5.2.2.3 OUTPUT

The output of sugeno fuzzy system changes as it provides the crisp values for the fuzzy input values. The distance of the nodes are calculated at 3 different points keeping the distance same as in mamdani type fuzzy system:

Distance is 0.106 and Weight is 0.923
Distance is 0.5 and Weight is 0.505
Distance is 0.188 and Weight is 0.868

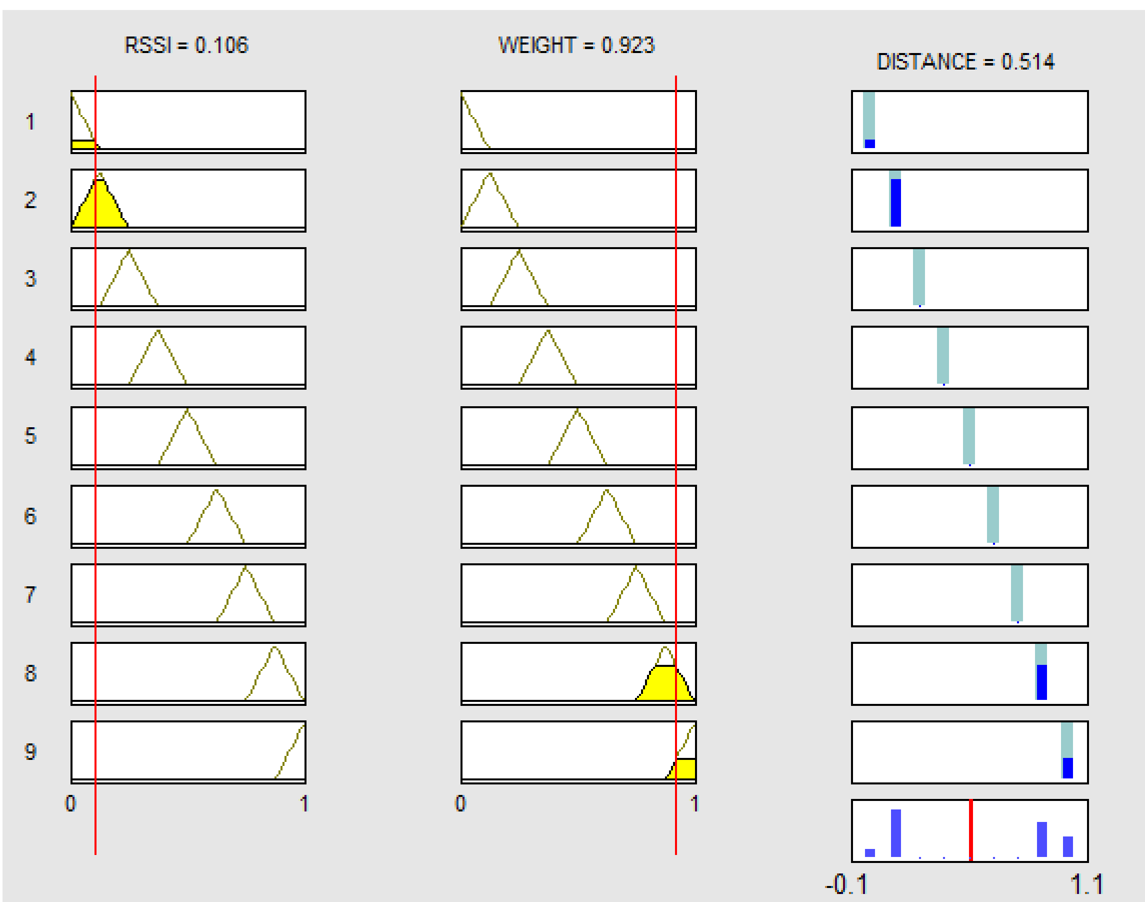

FIGURE 5.10: OUTPUT VALUE

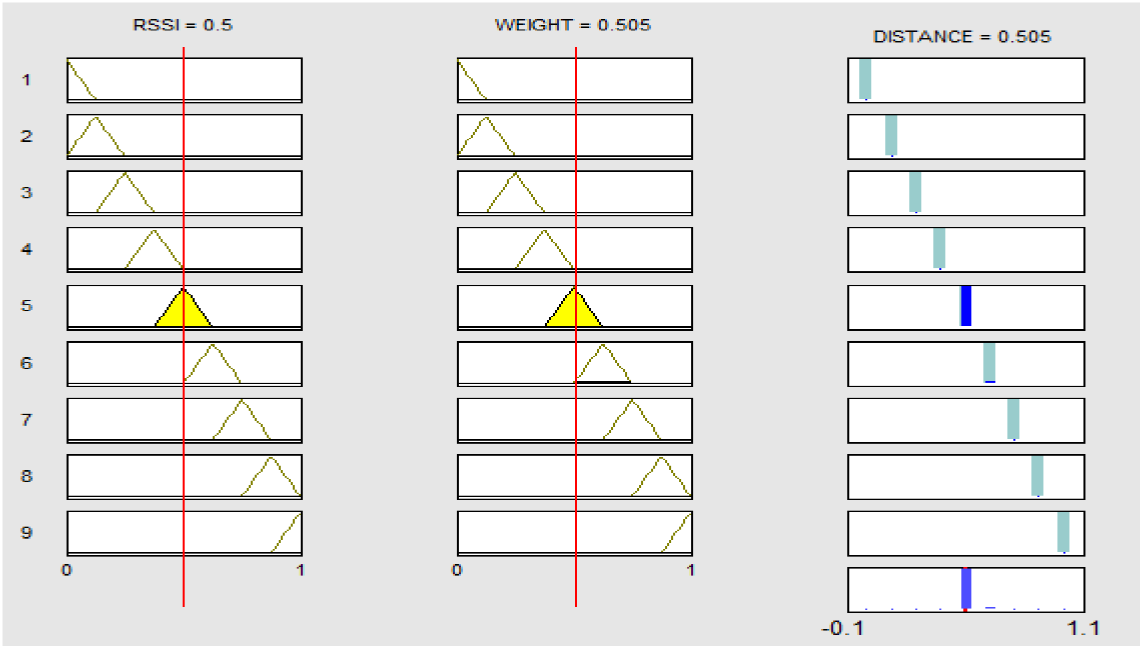

FIGURE 5.11: OUTPUT VALUE 1

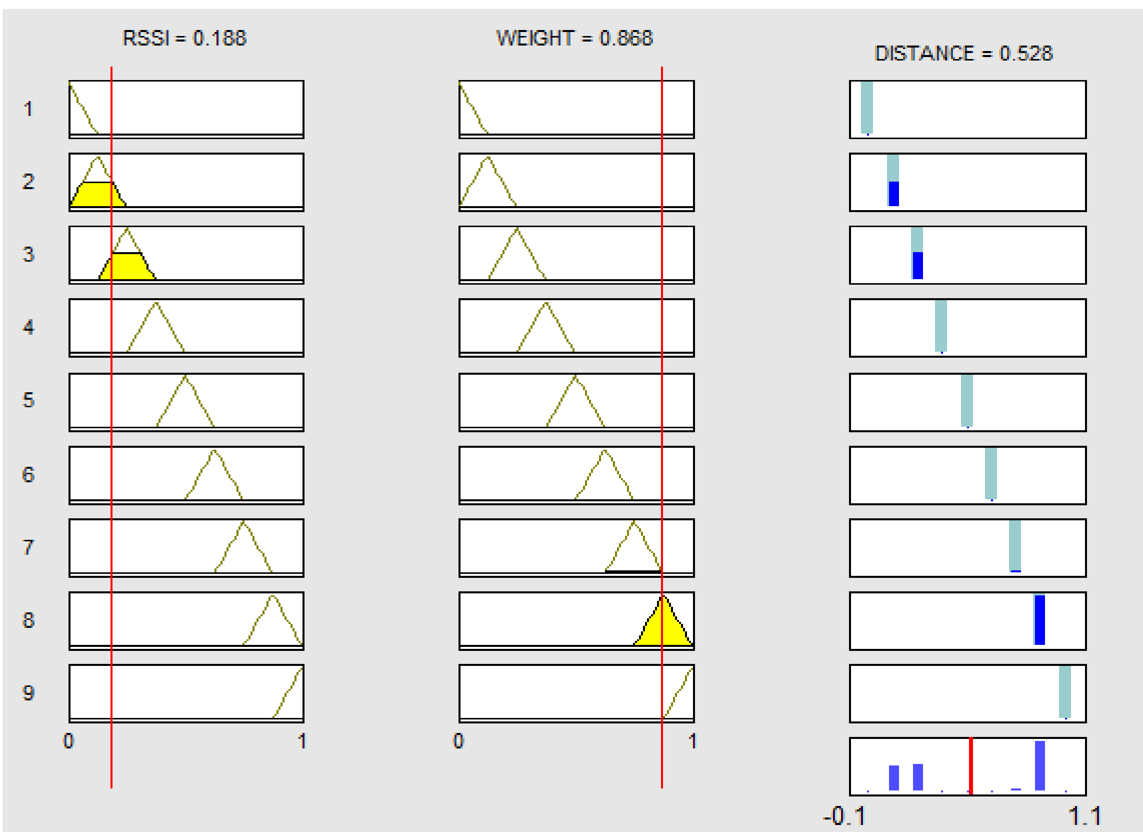

FIGURE 5.12: OUTPUT VALUE 2

The surface view of the function is seen as:

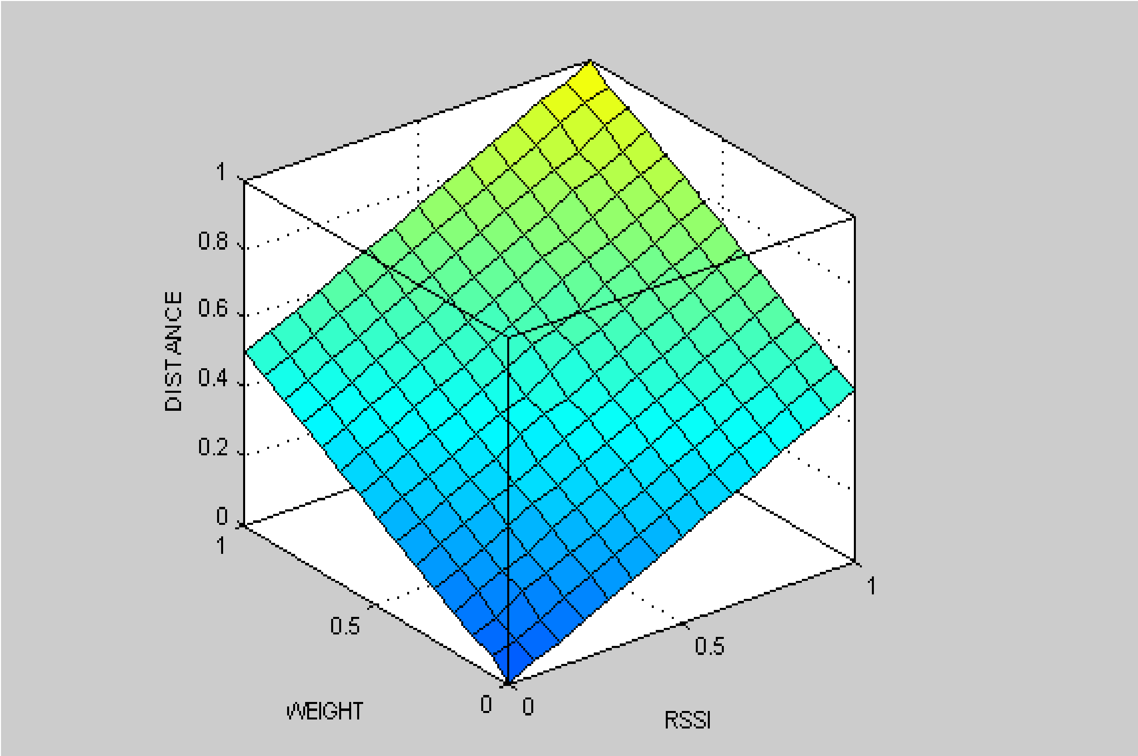

FIGURE 5.13: SURFACE VIEW OF OUTPUT VALUE

5.3 COMPARISON OF RESULTS

TABLE 5.3: OUTPUT COMPARISION

INPUT VALUES	DISTANCE_MAMDANI	DISTANCE_SUGENO
[0.106,0.923]	[0.496]	[0.514]
[0.5,0.505]	[0.506]	[0.505]
[0.188,0.868]	[0.498]	[0.528]

It can be seen from the table that interpretability is increased in mamdani type reducing the accuracy of the system.

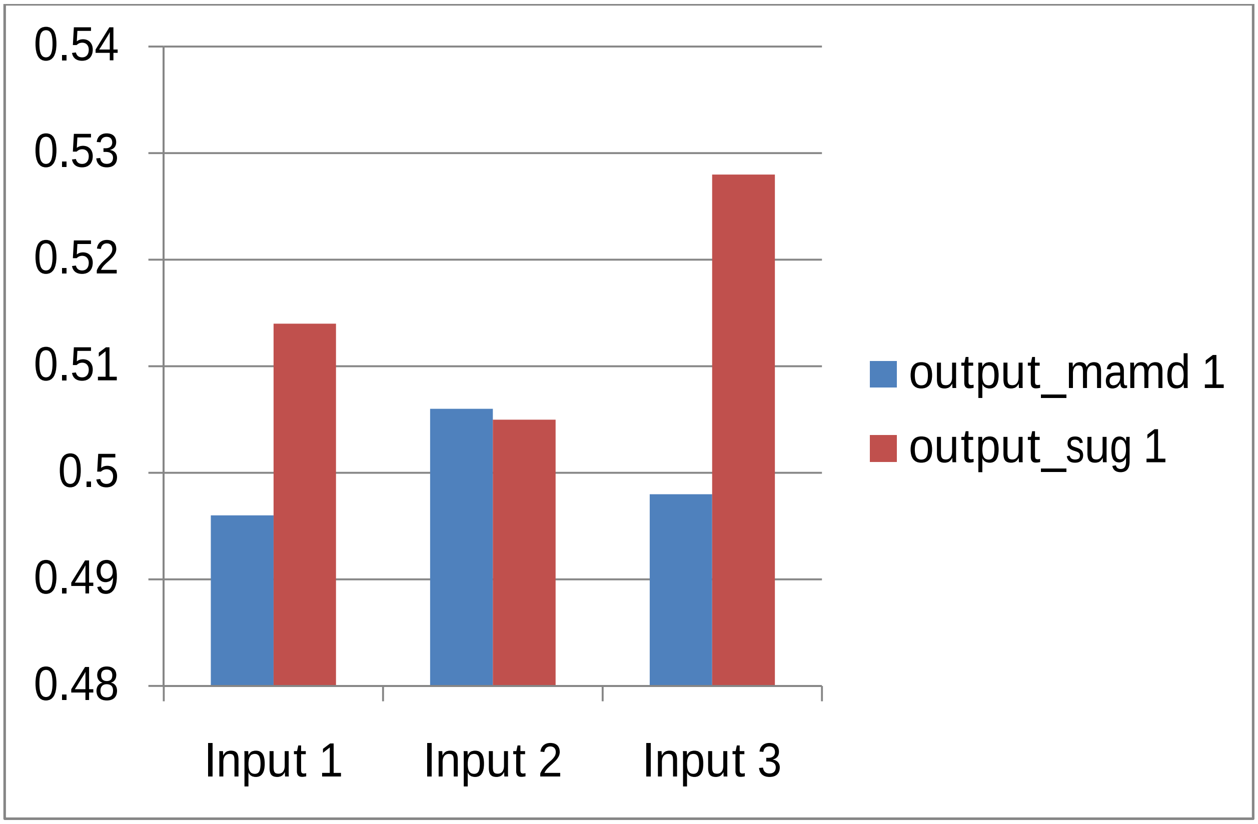

FIGURE 5.14: Comparisons of results

5.4 NODAL SECURITY

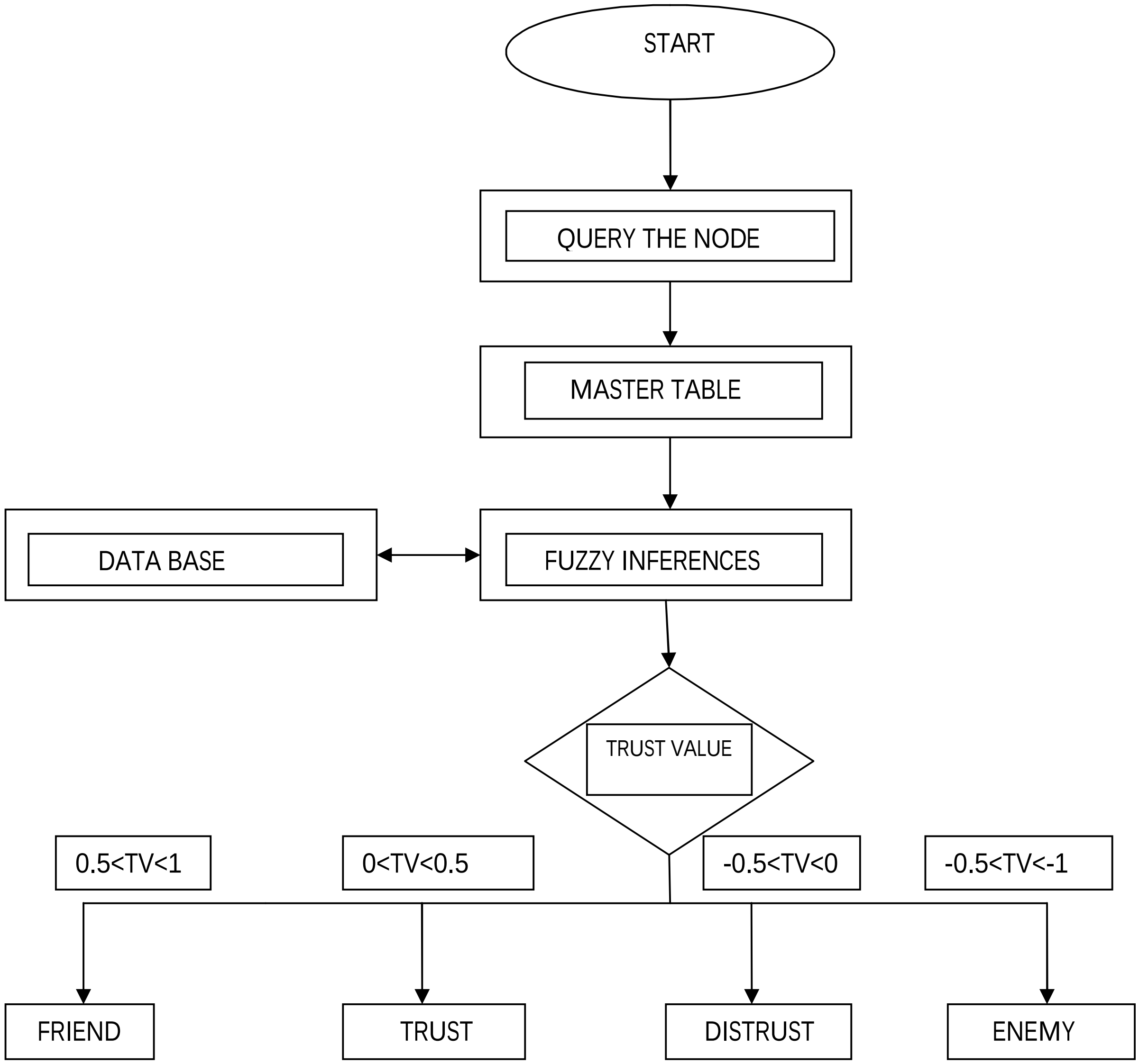

FIGURE 5.15: SECURITY FLOW CHART

Nodal security is one of the most important issues when dealing with wireless sensor network. A model for nodal security is presented. The packets send and received are checked for the values each and every time of sending and receiving values in the reference table. If there is very large difference between the nodes sending and receiving of the packets then such nodes cannot be trusted. The table is updated after every process. These values can be categorized in four groups of FRIEND, TRUST, DISTRUST and ENEMY. The friend and trust are in the safe zone whereas distrust and enemy are in unsafe zones for packet transfer.

5.4.1 INPUT VARIABLES

The send and received values are taken as input variables. The input variable table is given below:

TABLE 5.4: Input variables in fuzzy control system

PARAMETER	TYPE	LINGUISTIC VALUES
Input	send	Below avg, avg, high, very high
Input	receive	Below avg, avg, high, very high

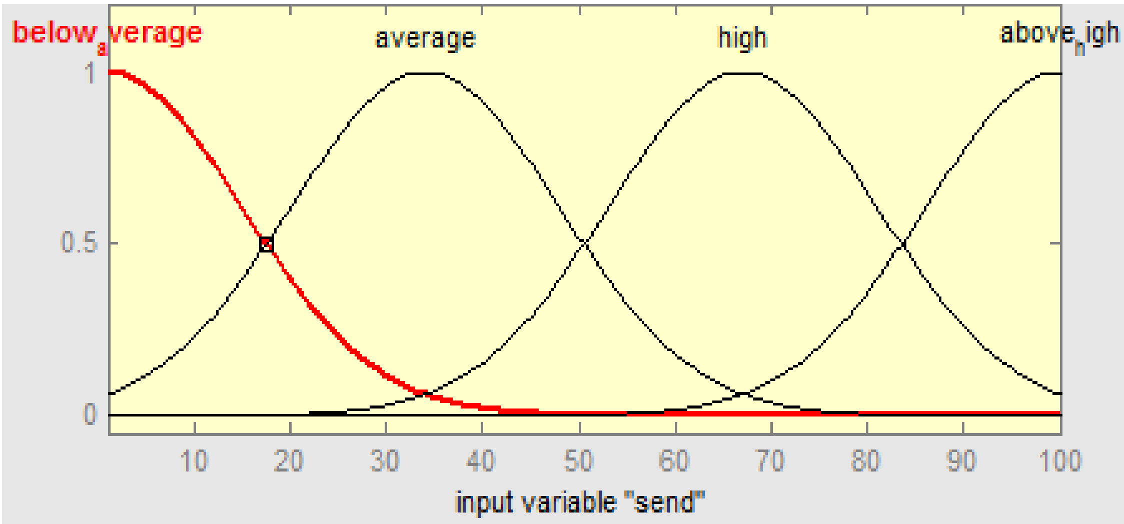

FIGURE 5.16: SEND FUNCTION

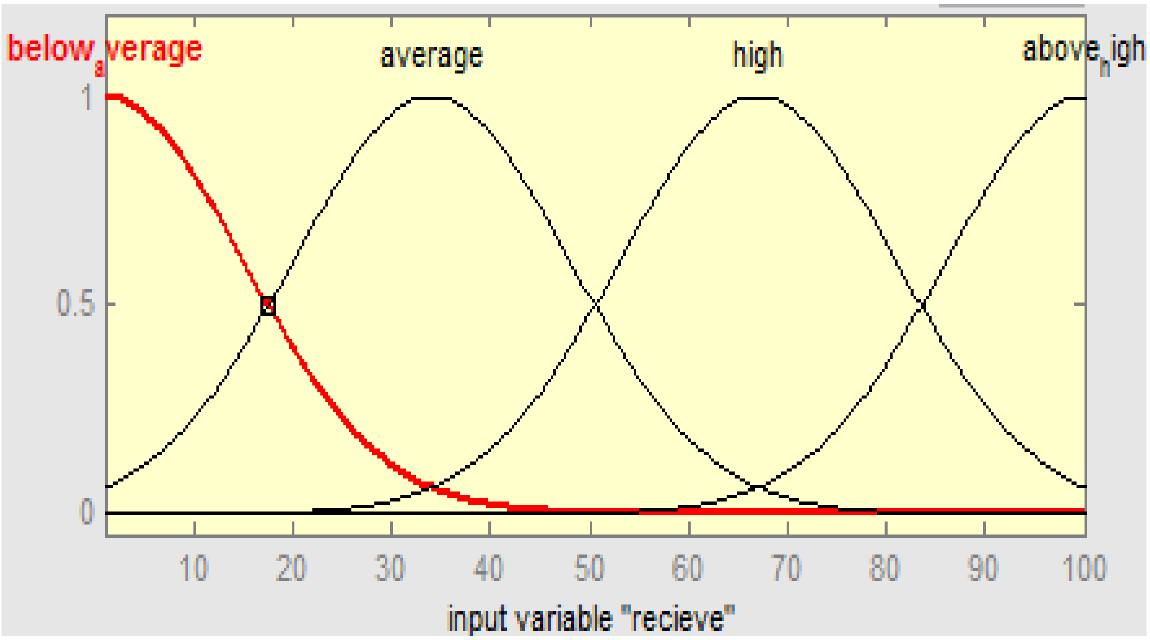

FIGURE 5.17: RECEIVED FUNCTION

5.4.2 INFERENCE RULES

For two input values four fuzzy sets are made. The inference rules are deduced with the send and received values of packet transfer which are as follows:

TABLE 5.5: INFERENCE RULES

RULES	SEND	RECEIVE	VALUE
i.	BELOW AVG	BELOW AVG	FRIEND
ii.	BELOW AVG	AVG	TRUST
iii.	BELOW AVG	HIGH	DISTRUST
iv.	BELOW AVG	VERY HIGH	ENEMY
v.	AVG	BELOW AVG	TRUST
vi.	AVG	AVG	FRIEND
vii.	AVG	HIGH	DISTRUST
viii.	AVG	VERY HIGH	ENEMY
ix.	HIGH	BELOW AVG	DISTRUST
x.	HIGH	AVG	DISTRUST
xi.	HIGH	HIGH	TRUST
xii.	HIGH	VERY HIGH	DISTRUST
xiii.	VERY HIGH	BELOW AVG	ENEMY
xiv.	VERY HIGH	AVG	ENEMY
xv.	VERY HIGH	HIGH	DISTRUST
xvi.	VERY HIGH	VERY HIGH	DISTRUST

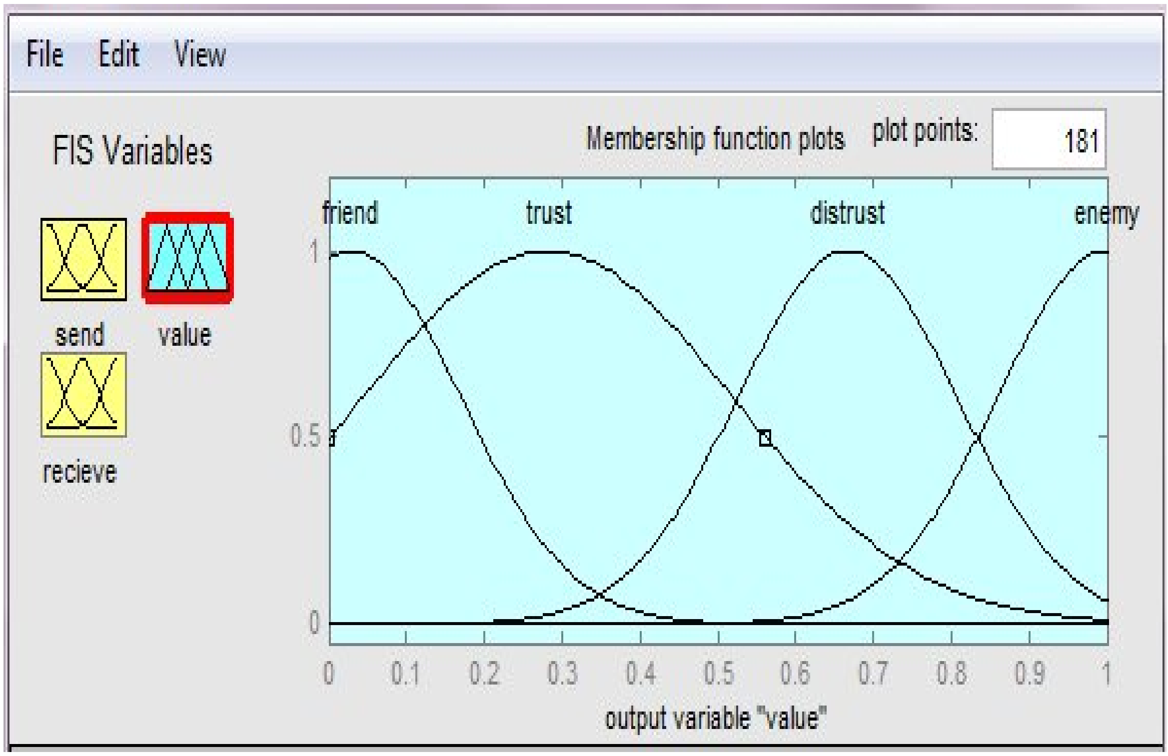

FIGURE 5.18: VALUE FUNCTION

5.4.3 OUTPUT

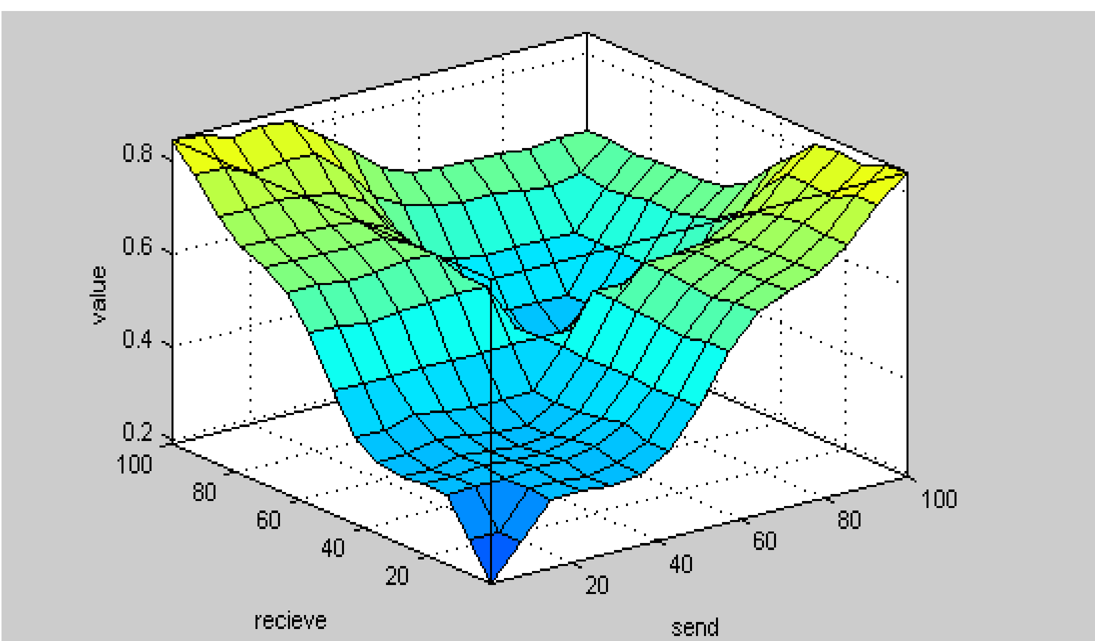

FIGURE 5.19: SURFACE VEIW OF OUTPUT

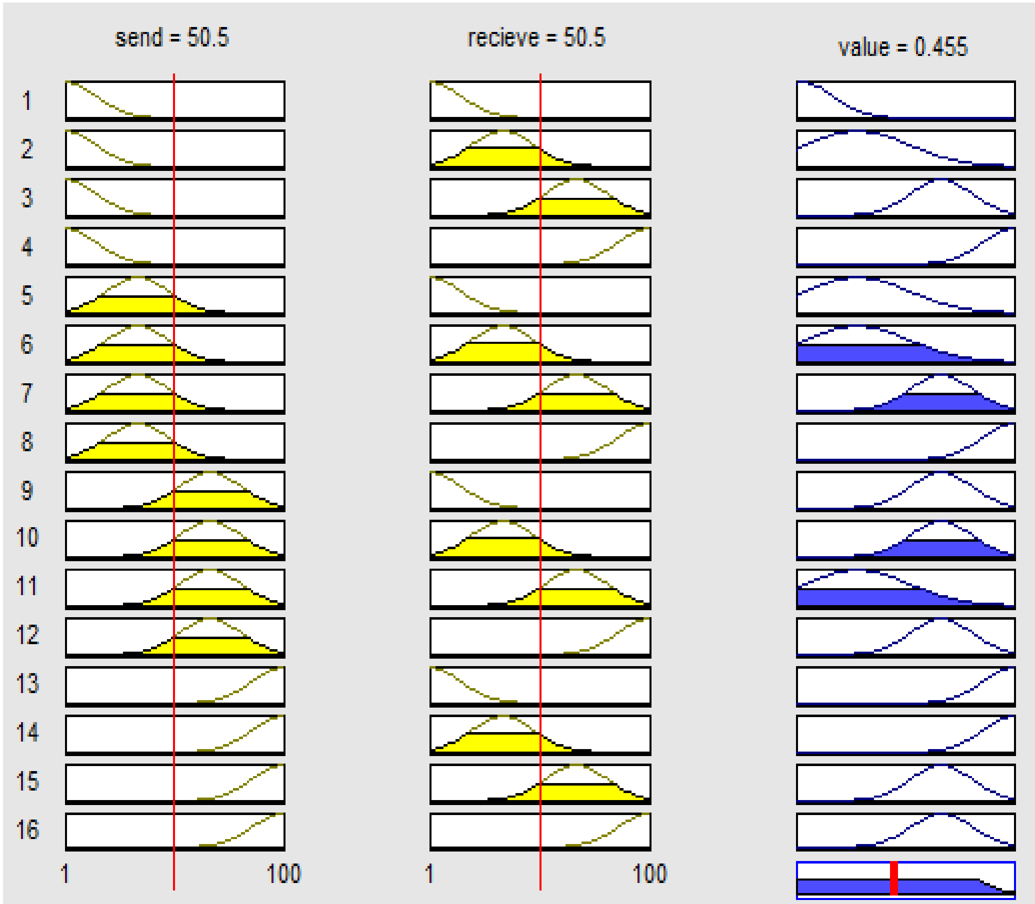

FIGURE 5.20: RULEVIEW OF OUTPUT

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

Node localization is important topic in wireless sensor network where accuracy of node estimation is required. Node estimation using range free technique is simple and efficient to use because no extra hardware implementation is required. There are many ways for implementing range free techniques for position estimation.

In this thesis RSSI is used to find the position. The RSSI and WEIGHT are used to find the distance between the sensor nodes and anchor nodes. The result is simulated using mamdani type fuzzy system and sugeno type fuzzy system. Fuzzy systems are used to feed the RSSI and WEIGHT.

The compressions between outputs of both fuzzy results are done to deduce the result. The final result shows that for accuracy sugeno type fuzzy system should be used whereas for flexibility and interpretability mamdani type fuzzy system is used.

Nodal security is one of the prime issues in wireless sensor networks. Vulnerability is mostly created by threats which act as potential danger to the network. If codes are provided to the nodes then we can easily identify the category in which they fall. This will help to transmit the data from the sender node to the receiver node.

The categorization can be divided into four portions: FRIEND, TRUST, DISTRUST and ENEMY.

FRIEND is the category where maximum value of trust is provided.

TRUST is the value with a little less trust value than FRIEND.

DISTRUST is the value provided when there is some danger in packet transfer.

ENEMY is the category where packet sending is prohibited.

6.2 FUTURE SCOPE

Addition of more sensor nodes will help to reduce the error rate of the sensor network. For security the next level can be implemented by providing the authentication to the nodes at each level.

The counter can be incremented and decremented as needed by the nodes. The proposed model for the future reference is presented bellow.

TRUST ARCHITECTURE

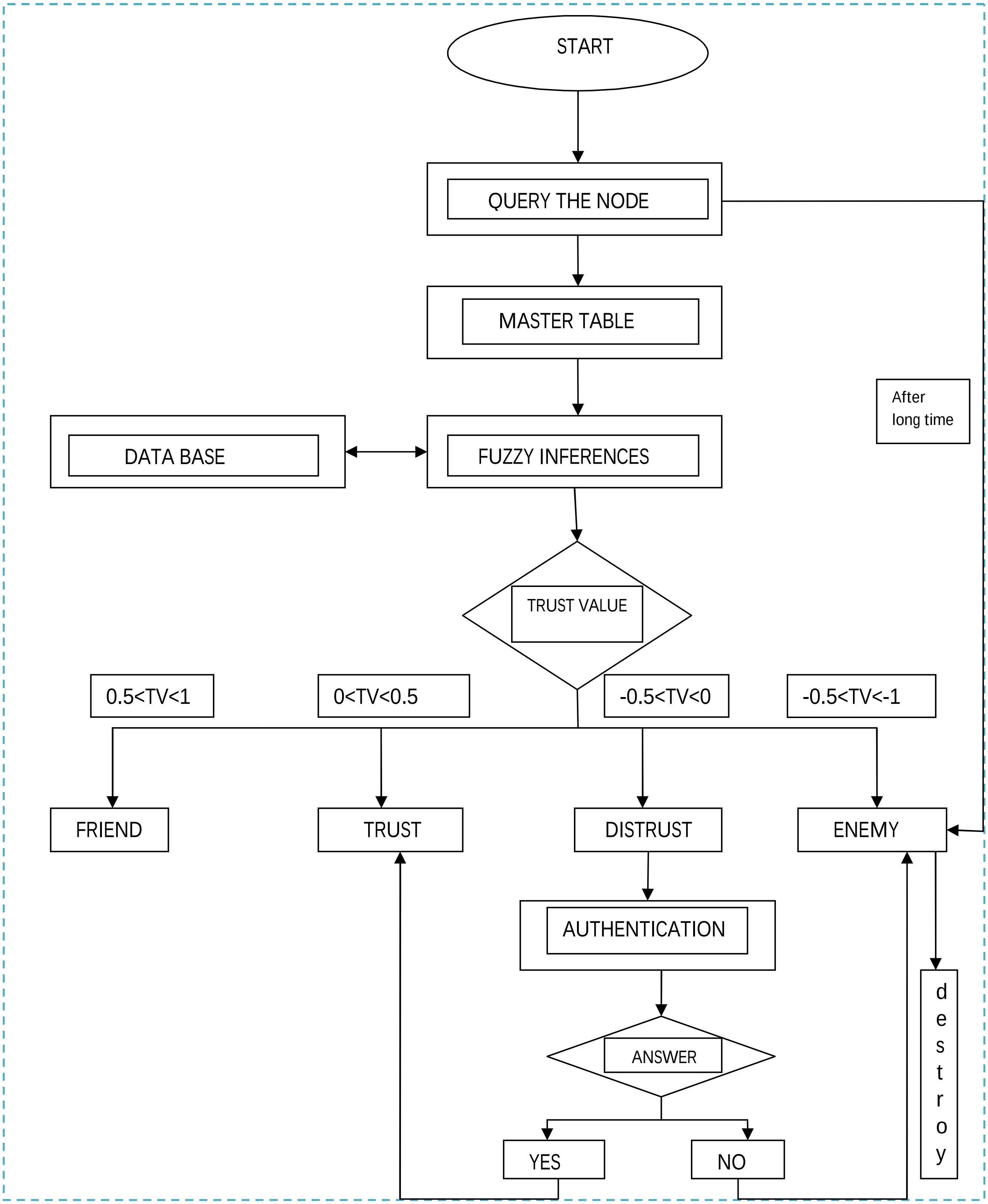

Figure 6.1 Security Architecture

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