MULTI PATH ENERGY EFFICIENT NEURO FUZZY BASED DYNAMIC CONNECTED DOMINATING SET IN WIRELESS MESH NETWORK

THESIS

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DECLARATION

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ABSTRACT

The Wireless mesh networks are becoming a promising communication technology for broadband wireless access by providing wireless backbone to mobile devices over multi-hop wireless communication systems.

A Wireless Mesh Network (WMN) is based on ad-hoc networks, where each node transfers data to and from an Access Point (AP) which is connected to the internet by a wired or wireless network. These AP need not to be in the reach of all the nodes in the network. Nodes around the AP forward the packets from the distant nodes to the AP. If there are a significant number of nodes in the network, neighbour nodes can transfer data with the AP in a few hops. Besides mobility, WMNs have the advantages viz., they can work in a decentralized fashion, are cheap with minimum investment for initial infrastructure, more reliable, scalable and provide increased coverage.

In WMN, transfer of data takes place to and from the AP. Each node sends route requests to its neighbours. When the requests reach the different AP's, they send back a route reply. The sending node receives all these replies and decides which route and AP to use based on different conditions.

Since transfer of data in ad-hoc networks is similar to this, the existing ad-hoc routing protocols like DSR and AODV are used. But these protocols assume some properties of ad-hoc networks that are no longer true for WMN. Quality of Service (QoS) is a key function for the transmission and distribution of digitized information across networks. It has two main objectives: finding routes that satisfy the QoS constraints and making efficient resource utilization. Unfortunately, several factors can cause poor performance. So many problems still exist such as data loss because of overloaded incoming and outgoing message buffers, packet delay or expiration when residing in large queue or when using unsuitable routes.

To overcome the problem by integrated stateless cross-layer QoS protocol based on fuzzy logic, wireless mobile ad-hoc networks can be adapted. The choice of using fuzzy logic is justified by the fact that fuzzy logic is well adapted to systems characterized by imprecise states, as in the case of ad- hoc networks. The fuzzy approach aims to improve the control of traffic regulation rate and congestion control. The fuzzy logic based routing algorithm is taken to provide the optimal best case performance on all possible traffic demands faced by users in the wireless mesh network. The goal is to minimize the maximum traffic of oblivious intrusion sets in the network. It deals with traffic performance and then avoiding the congestion on the network.

However, the routing protocol can decide the route based on the number of overloaded nodes in each of the available route. The route with least number of overloaded nodes is chosen as the best route. If two routes have the same number of overloaded nodes, then the one with the lesser number of hops is chosen. But this method is not a sufficient condition to check the load in a route. They have selected a best path route and information on the system. It has more importance to send the data from source to destination on the network. The protocol selects the path visiting the nodes with the highest residual energy. Each flow is ensured to have enough energy on the selected path and depleted nodes are avoided. However, the path selected does not minimize the energy needed to transmit a flow packet from its source to its destination. Hence, the network lifetime should be maximized and improved network performance on the system should be attained.

The major performance demands for all the protocols are the number of routes established during route discovery, maximum data packet delivery, high network throughput, average energy conserved, minimum end-to-end data packet delay, computational complexity of the algorithm and finally, improved network. In order to improve the network performance, a data transfer using a shortest path routing model in CDS system can be implemented.

In this approach, the multiple shortest paths between two exchanges are used. When a route fails or reaches its capacity, calls are routed through a longer, alternate path. The use of multiple paths is time based and it has been explored in different areas of networking. In the traditional circuit switching network, alternate path routing was used to decrease the probability of call blocking. In data network, the idea of using multiple paths for end-to-end transport is used to minimize the overall delay in the network.

This work can be concentrated further to increase the combination of energy efficient and security based connected dominating sets on the network. Network throughput, delivery ratio, packet delay and energy model parameters are taken from this network. It mainly focuses on the energy efficient, energy consumption and security based data transfer on the network.

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LIST OF SYMBOLS AND ABBREVIATIONS

AP	- Access Point
AODV	- Ad-hoc On-Demand Distance Vector
CSPR	- Conditional Shortest Path Routing
CDS	- Connected Dominating Set
D	- Destination
EENF	- Energy Efficient Neuro Fuzzy
FL	- Fuzzy Logic
MEE	- Multi path Energy Efficient
MPR	- Multi Point Relay
NDD	- Neighbour Discovery Distance
NF	- Neuro Fuzzy
PDF	- Packet Delivery Fraction
Pr	- Packet received
Ps	- Packet send
QoS	- Quality of Service
QoSR	- Quality of Service Routing
RREP	- Route Reply
RREQ	- Route Request
SNF	- Scheduling Neuro Fuzzy

Tr	-	received Time
Ts	-	send Time
WMN	-	Wireless Mesh Network

CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Wireless Mesh Network

Wireless Mesh Networks (WMN) is the class of network emerged recently. The key part of WMN contains wireless mesh routers and wireless mesh hosts, in addition to access points so as to act together as internet routers and wireless interlock routers. The mesh routers within a WMN are fixed and they form the wireless mesh moral fiber, which provides multi-hop communication beginning mesh hosts to either other mesh hosts or the Internet via access points. The mesh hosts can be fixed or movable and they can form a wireless local area network (LAN) or a set of mobile connections (MANET), and they can be in touch with the external world using mesh routers.

A WMN is enthusiastically self-composed and self-implemented with nodes in the network by maintaining mesh connectivity between themselves. The advantages of WMNs are low installation cost, large-scale use, dependability, and self-management (Bashar A and Parr G 2010). A typical example of WMN is deployed in a new town. The wireless mesh routers are installed on the roofs of the building to cover up a whole town. It is moreover possible to put into practice a wired network in the region.

A WMN incurs a much lower fixing cost. One more example is a WMN working in a country side with mountains and forests because it is very tough to build a wired arrangement on mountains and forests. Deploying a WMN, on top of the additional handover, is fairly easy.

The history of wireless networks started in the 1970’s and the interest has been growing ever since. At present, this sharing of information is difficult, as the users need to perform administrative tasks and set up static, bi-directional links between the computers. This motivates the construction of temporary networks without wires, communication infrastructure and administrative intervention. Such interconnection among mobile computers is called an Ad-hoc Network (Kaloxylos A 2009). Ad-hoc networks are emerging as the next generation of network and defined as a collection of mobile node forming a temporary (spontaneous) network without the aid of any centralized administration or standard support services. In Latin, ad-hoc literally means “for this”, further meaning “for this purpose only” and thus usually temporary.

An ad-hoc network is usually considered a network with nodes that are relatively mobile, compared to a wired network. Hence the topology of the network is much more dynamic and the changes are often unpredictable unlike the wired network. This fact creates many challenging research issues, since the objectives of how routing should take place are often unclear because of the different resources like bandwidth, battery power and demands like latency (Popescu A and Ermana D 2010). MANETs have several salient characteristics: 1) Dynamic topologies 2) Bandwidth constrained, variable capacity links 3) Energy-constrained operation 4) Limited physical security.

Wireless mesh network nodes equipped with a large number of small energy devices have become a hot research and have a lot of potential applications including environmental monitoring, military detection, health monitoring, industrial control and home networks. But in practical applications, to meet the demands of the various types of applications for the technologies of sensor networks.

The Energy consumptions are effectively reduced by organizing mesh nodes, so energy-efficient routing protocols are designed by the structure. Currently, a number of distributed protocols are developed (Zeynali M and Khanli L M 2009). In according to the networks, homogeneous or heterogeneous, to which the protocols are adaptive protocols categorized into homogeneous clustering protocols and heterogeneous protocols. Due to the dynamic, complex nature of energy configuration and network evolution, it is very difficult to design a clustering protocol which can save energy.

1.2 Network Model for Key Management

Most of attacks on routing protocol are due to want of encryption for some fields in the routing packets. Unauthorized modification of such fields could cause serious security threats. To ensure secured communication, a composite key management on scheme is needed. It is a door step key management scheme in which certification services are distributed among ‘n’ serving nodes. Each serving node generates partial certificate.

Inter Cluster Communication

The communication among the clusters is carried out using the virtual path established between the cluster heads (CH), two different clusters *C1* and *C2* under cluster heads CH1 and CH2. *A1* wants to communicate with *B2*. The procedure for inter cluster routing is described in following figure 1.1.

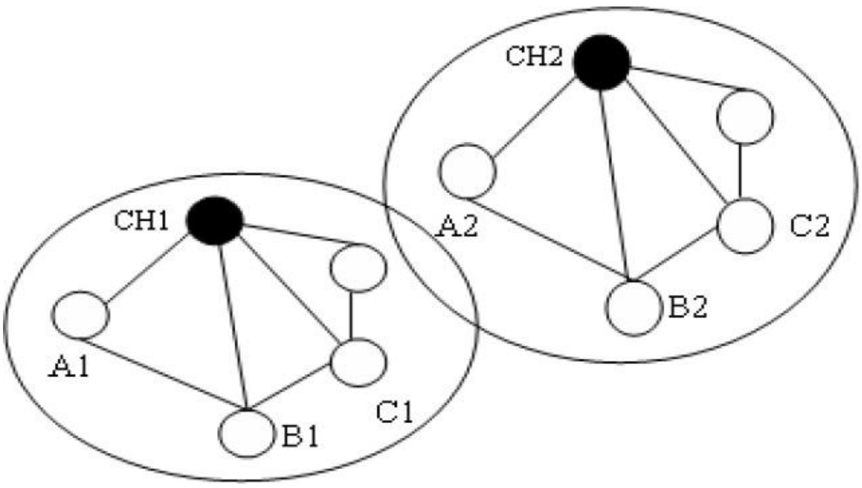

Figure 1.1: Inter Cluster Method

1: *A1* asks for CH1 for *B2*'s public key

2: CH computes trust ability of node *A1*

TV (*A1*) = compute trust (*A1*, N (*A1*))

3: If TV (*A1*) >= Threshold

3a: CH1 search for node *B2* in its member list

3b: if *B2* not in CH1 member list

3c: CH1 send SEARCH_REQUEST to its neighbouring cluster head CH2

3d: CH2 search for *B2* in its member list. If found, do step 3e: to 3h: else send FAILURE message to CH1.

3e: CH2 send EKeyCH (PKey (*B2*)) to CH1

3f: CH1 decrypt the message and send EPKey (*A1*) (PKey (*B2*)) to *A1*

3g: *A1* sends EKey (B2) (Message) to CH1

3h: CH1 forwards encrypted message to CH2 which in turn forward the message to *B2*.

Dominating Set in Wireless Mesh Network

Algorithm that constructs a CDS can be divided into two categories. Such as centralized algorithm and decentralized algorithm. In centralized algorithm, all the nodes in the network must know the complete network topology (Nieto A and Lopez J 2012). Cluster based algorithm is one of the decentralized algorithms. The network is partitioned into clusters and CH is elected for each cluster. In another phase, a virtual backbone that connects CHs is established. The distributed cluster based algorithm is used to construct a CDS. Several clustering algorithms have been proposed to elect CH that has maximum id, maximum node degree, and maximum residual energy. Therefore distributed cluster based algorithm is used to construct a CDS.

1.3 Traffic Balancing in Mesh Network

In this method, nodes are designated as overloaded based on the medium usage around them. If medium usage exceeds a specific threshold value, then the node can be declared as overloaded. One method of choosing a route is to consider the number of overloaded nodes in a route. The routing protocol can decide the route based on the number of overloaded nodes in each of the available routes. The route with least number of overloaded nodes is chosen as the best route. If two routes have the same number of overloaded nodes, then one with the lesser number of hops is chosen. But this method is not a sufficient condition to check the load in a route.

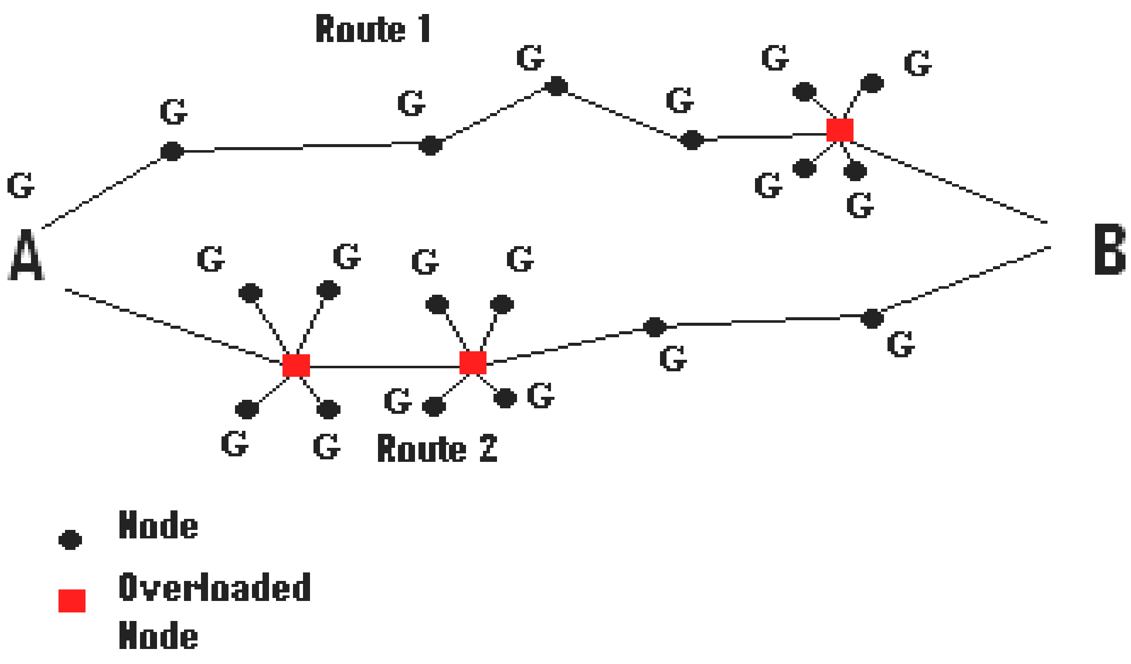

Figure 1.2: Traffic Balancing in Wireless Mesh Network

It is clear here that the cumulative traffic serviced by the node is also an important factor to be considered and it is not enough if only the number of overloaded nodes in the route is considered. Suppose a node on the route is having a lot of collisions around it and if a high traffic is sent towards this node, then a lot of packets will be dropped due to buffer overflow during the back off period. The traffic balancing in network is shown in figure 1.2.

1.4 Fuzzy Logic in Wireless Mesh Network

Fuzzy Logic (FL) is a simple but influential line of attack in logic structure. It was formerly conceived in the context of building control systems which incorporate a simple rule-base to solve a control problem. In the situation of modeling protocol for an Ad-hoc Network, most of the parameters are imprecise or not so-well defined. For example, mobility can be expressed in indistinct terms by means of a motion vector (Shekhar T P 2012). Similarly, distance confines, power available at the nodes and traffic density are parameters where determinations of precise values are not convenient and not important either.

Fuzzy Logic System

Fuzzy logic tries to replicate the thought of human logic. Fuzzy Logic offers various unique characteristics so as to stay as the best alternative for control problems. It’s robust as it does not prefer any standard inputs. The output control is a flat control function even with those varied inputs.

The FL controller can be changed and tweaked to improve or alter the performance of system with some user defined rules. FL deals with the information analysis by using fuzzy sets that can be represented in linguistic terms. The real value ranges over the mapped set (domain), and the membership function is termed fuzzy set (Zafeiris V E and Giakoumakis E A 2005). A truth value between 0 and 1 (to all the points in the domain) is being done by membership function. Various fuzzy sets can be used (triangular, beta, PI, Gaussian, sigmoid etc.) depending on the membership function's shape. Basically a fuzzy logic system (FLS) comprises three parts:

- Fuzzifier
- Inference Engine
- Defuzzifier

The fuzzification process prepares the crisp inputs to be fuzzifier. These fuzzifier values are then handled by the inference engine, which has a rule base and various methods for inferring the rules. Expert rules from numerical data extraction form the rules (FLS heart). The antecedent (IF-PART) and consequent (THEN-PART) are parts of a rule. For a certain fuzzy set, a common fuzzification process is characterized by the membership functions, termed fuzziness. The rules relate the input with the output fuzzy variables using linguistic variables that are represented with a fuzzy set & fuzzy implication operators AND, OR etc. Finding a crisp output value from the fuzzy solution space is the defuzzification.

Fuzzy Logic Control

The representation of fuzzy logic control consists of a fuzzifier, fuzzy rules, fuzzy inference engine, and a Defuzzifier. The most frequently used fuzzy inference technique is called Mamdani method.

The process is performed in four steps:

• Fuzzification of variable energy, concentration and centrality: Taking the hard inputs from each of these and determining the amount to which these inputs belong to every suitable fuzzy set.

• Rule evaluation: Taking the fuzzifier inputs, and applying them to the antecedents of the fuzzy rules. It is followed by the implementation of resulting membership function.

• Aggregation of the rule outputs: The process of fusion of the outputs of all rules.

• Defuzzification: It changes the fuzzy set's total output into a single hard number.

Fuzzy Logic in Wireless Multi Hop Networks

This logic has functional problem to resolve that are either difficult to tackle mathematically or where the use of fuzzy theory provides improved performances (Niyato D and Hossain K 2009). Fuzzy QoS is based on fuzzy logic for wireless mobile ad-hoc networks. The choice of using fuzzy logic is justified by the fact that fuzzy logic is well adapted to systems characterized by imprecise states, as in the case of ad-hoc networks. The fuzzy approach aims to improve the control of traffic regulation rate and congestion control of multimedia applications. Fuzzy QoS uses fuzzy thresholds to adapt the traffic transmission rate to dynamic conditions.

The fuzzy engine may distinguish congestion from channel error conditions, and consequently assists the TCP error detection. Investigations have been made on the issues for improving the reliability and accuracy of the decisions in wireless ad-hoc networks. This approach offers a way of integrating wireless units measurement results with association information available or priori derived at aggregating nodes. It is also used for describing both wireless unit results and association information with consideration given to both Neuro-Fuzzy and probabilistic model methods (Bourdoucen H and Azani F 2013). The information sources available in the system are classified according to the model (fuzzy or probabilistic), which seems more feasible to be applied.

Fuzzy Routing

In WMN network, the various constraints like collisions, traffic level, buffer occupancy, battery power, etc., need to be considered. It is not enough if only one constraint is considered. This is because of the complex relationship existing between different constraints. Multi-constrained routing is based on NP complete problem and does not have a polynomial solution. It is required to use various heuristics and soft computing techniques to solve them.

Fuzzy scheme is the most suitable creation of best direction-finding decisions connecting numerous constraints and many objectives. There are several studies of fuzzy routing where a fuzzy system is implemented in excess of traditional methods like DSR to multi-hop routes (Wankhade S B and Ali M S 2012). Routes are determined based on the metrics join stoppage. Fuzzy routing algorithm is based on more than a few metrics for mesh network.

A fuzzy logic system eliminates unnecessary routes by removing links not accepted by the system to be considered. An adaptive algorithm is based on fuzzy logic to change the security level of mobile node considered a fuzzy for making routing decision in WMN traffic gets spread across the system for maximum bandwidth usage (Tabash K and Mamun M A A 2010).Various constraints are considered such as buffer occupancy, residual energy of nodes and the distance of source (hops) from the AP.

Fuzzy Rule Base and Method for Determining Routes

It modifies the AODV and introduces the fuzzy logic multi-criteria for assigning active route lifetime (LT) of each entry in routing table. To prevent low bandwidth and overhead of transmission, the routes are determinate dynamically. Therein, a reliable route should have maximum expiry time and substituted when it is unavailable (Lertsuwanakul L and Coltzau H 2010). A source node in ad-hoc network has multi-path to each destination. If the route is not used for a period of time or the lifetime is low, the route entry has high probability to expire due to high probability of its instability.

Shortest Path in Fuzzy System

The fuzzy logic routing protocol is compared to the shortest path method and thermal approach by fixed functions algorithm. Since the approach runs in decentralized network, each node knows only its neighbourhood peers. The route decision is made step by step when it holds message. The shortest path method finds the route in terms of hop-count then the message is forwarded to the shortest neighbour to destination. Other constraints are not considered.

The thermal approach is used for considering for buffer usage level. The functions for probability to select either low buffer route or shortest way are predefined.

1.5 Neuro-Fuzzy Genetic based Network

The Hybrid Neural Network functions with the support of Fuzzy Logic, operating on inputs (which are unclear in nature) and generating a set of solutions in the solution space with minimal search using Genetic algorithm. The neuro-fuzzy genetic based network is shown in figure 1.3.

Neuro Fuzzy System

Neuro fuzzy refers to grouping of fuzzy set theory and neural network with the compensation of both. Fuzzy logic considerably simplifies design complexity. Most real life physical systems are actually non-linear systems (Chelliah M and Sankaran S 2012). Commonly used approximation methods to handle non linearity include linear, piecewise linear and lookup table. A linear approximation is simple with limited control presentation.

1.6 Network Topology for WMN

In Cluster-based scheme, the network is divided into groups of nodes, which saves energy and increase the network lifetime by utilizing concept of sleep mode so that only nodes with data to be sent are awake. Within each cluster group one node is selected to be a cluster-head (leader node). The leader node receives data from its group members, combines and sends them to its master node.

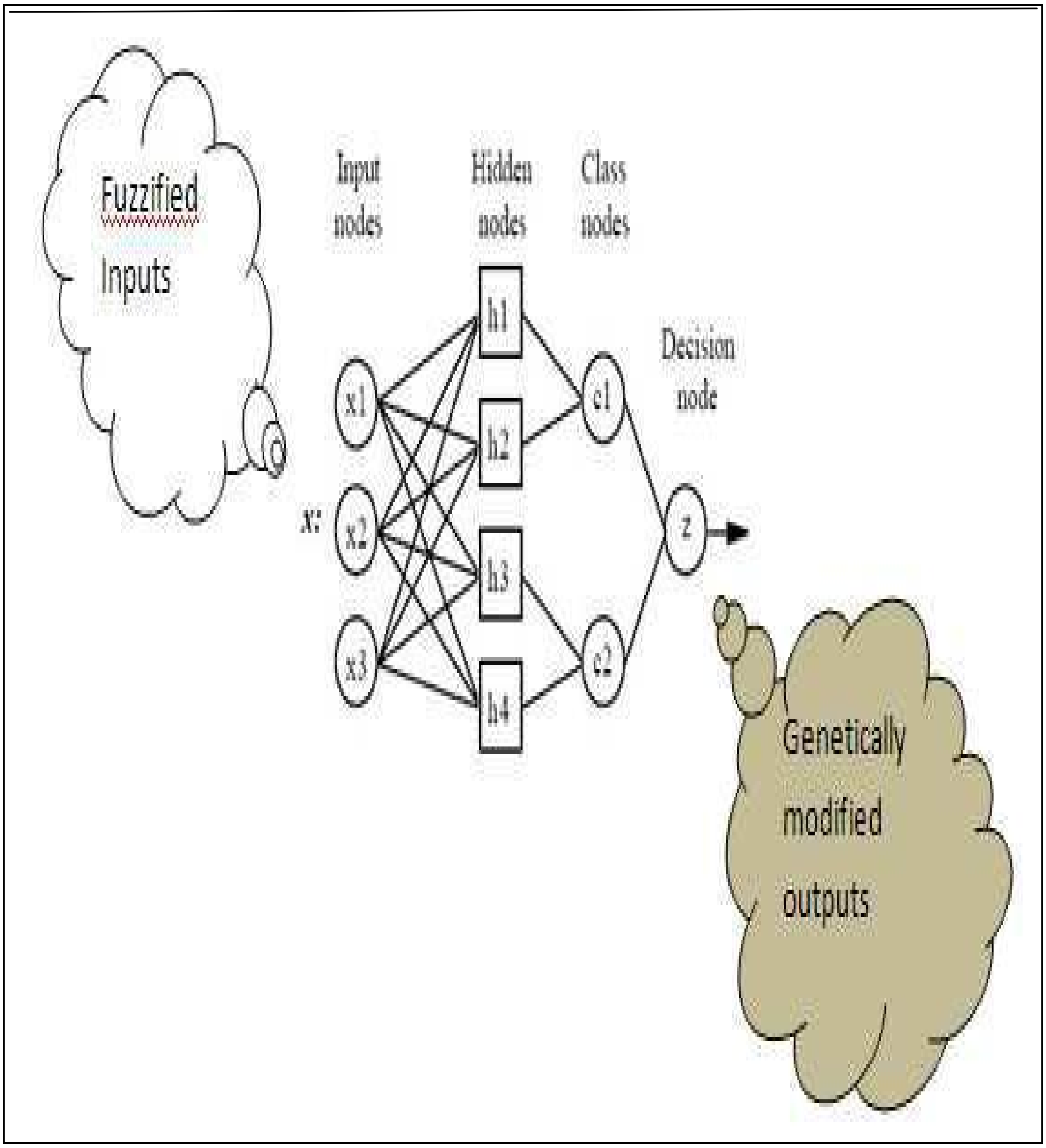

Figure 1.3: Neuro-Fuzzy Genetic based Network

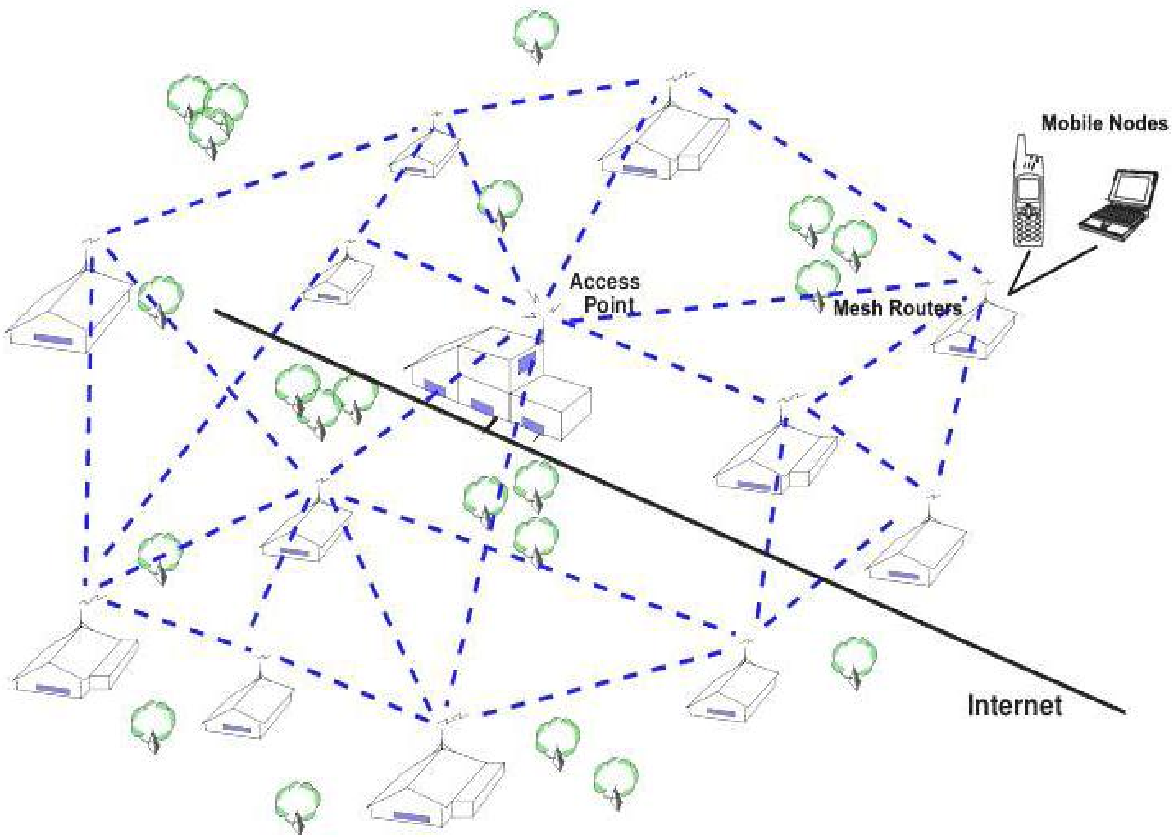

Figure 1.4: Wireless Mesh Network Topology

Protocols assume some properties of ad-hoc networks that are no longer true for WMN. In case of ad-hoc networks, most of transfer might be among different computers in network itself and the network usage is spread over different routes. Unlike ad-hoc networks, in WMN most of the data transfer is between the nodes and few AP's. Moreover, most of the ad-hoc protocol chooses the shortest route to the destination (Tripathi M R and Gaur K 2010). Some of the paths in the network are more utilized compared to others. Hence, when protocols are used in WMN it leads to congested routes.

Some of the AP's are more used while others have a low traffic. This might lead to busy nodes in some routes, while others are rarely used. Presence of overloaded nodes in a route may lead to high collision rates, packet drops in the queue and long delays at the queues and also this leads to wastage of the bandwidth. Hence, there is a great demand for an efficient routing protocol for WMN. The WMN topology is shown in figure 1.4.

Energy Efficient in WMN

At present the increasing concentration is mainly on WMNs in which constructing an energy-efficient clustering protocol is the major thought. To enhance the lifetime of the network the hierarchical clustering algorithms are of greater importance. Setup phase and steady state phase are present in every clustering algorithm. The cluster head selection is the main goal of these algorithms. The effect of heterogeneity nodes in terms of their energy is hierarchically clustered with wireless sensor networks. An assumption is that the supplementary energy resources equip a percentage of the population of sensor nodes. Another assumption is that the sensor nodes are not mobile but they are randomly distributed beside with information concerning the size of the sensor field and the coordinates of the sink (Senthil K R 2012).

The presence of node heterogeneity is not attained by every sensor nodes that are equipped with the equal amount of energy is an assumption in homogenous clustering protocols. An energy efficient heterogeneous clustered approach for wireless sensor network is based on weighted election probabilities of each node. These nodes elect a cluster head considering the residual energy in each node.

1.7 Problem Formulation

Many researchers have studied the use of shortest path in wireless mesh network with focus on survivability issues and addressed the problem of traffic congestion along finding the shortest path. Existing data transfer techniques may cause time delay. In survivable wireless mesh network, routing protocols involve major problem based on routing, such as traffic, delay, and low network performance. It is based on survivability requirement of the network, various routing scheme faces degradation of network performance, high energy consumption and link failure.

Maintaining the performance of WMNs in the face of dynamic link failures remains a challenging problem. Such failures can be withstood maintaining the required performance by enabling WMNs to autonomously reconfigure channels and radio assignments. Recovering from link-quality degradation the quality of wireless links in WMNs can degrade due to severe interference from other collocated wireless networks. By switching the tuned channel of link to other interference-free channels, local links can recover from such a link failure. In heterogeneous channel availability, links in some areas may not be able to access wireless channels during a certain time period (spectrum failures) due to spectrum etiquette or regulation.

In order to develop a system that allows WMNs to autonomously change channel and radio assignments, they have already studied energy efficient based routing on network but further concentrated to implement a data transfer using a shortest path routing model in CDS system.

Therefore it is required to take parameters such as throughput, delivery ratio, and packet delay and energy model. It mainly focuses on the energy efficient and energy consumption in the network.

This work aims to employ fast and efficient routing protocol in wireless mesh network which implements a data transfer using shortest path routing model in CDS system. This scheme is the combination of the energy efficient and security based connected dominating sets in the network. Performance analysis on the existing techniques is also studied. Evaluation of this work is based on theoretical and performance analysis.

1.8 Organization of the Thesis

This thesis deals with the novel shortest path technique for network survivability in wireless mesh networks to enhance the energy efficient and security based data transmission. This proposes a theoretical and performance analysis based on which results were obtained and simulation has been carried out to ensure the hypothesis. The robustness of this system towards the contention has also been studied and a remarkable improvement is obtained. The thesis is organized as follows:

Chapter 2: Literature review from existing research work

Chapter 3: Implementation of Fuzzy Logic Routing for Wireless Mesh Network

Chapter 4: Implementation of Neuro Fuzzy Routing for Wireless Mesh Network

Chapter 5: Implementation of Neuro Fuzzy Scheduling based Connected

Dominating Set in Wireless Mesh Network

Chapter 6: Implementation of Energy Efficient Neuro Fuzzy Based Dynamic Connected Dominating set with Multi point Relay in Wireless Mesh Network

Chapter 7: Performance Analysis of Multipath Energy Efficient Algorithm

Chapter 8: Conclusion and future scope of the research work

CHAPTER 2

LITERATURE REVIEW

The literature survey focuses its attention on wireless mesh networks, particularly to analyze the routing problem in the network, localize and recover the network from link failures and optimize the utilization of resources available in the network.

In wireless mesh network, IEEE 802.11 encountered scalability problems caused by link-level protocol, such as data processing in the network. Wired Ethernet uses carrier-sense multiple-access to detect Ethernet collisions, which cannot be done with RF signal (Tran A H and Mellouk A 2011).

In addition, Ethernet has several orders of magnitude more bandwidth to solve this challenge. But in all-wireless environment, there is far less bandwidth than a wired network and the AODV protocol imposes capacity limitations, especially in single-radio Access Points (APs).

Subsequent wireless mesh solutions used separate radios for access and backhaul to mitigate the effects. Some product uses multiple radios for backhaul and directional antennas to minimize self-interference, which can dramatically increase the number of collisions in large networks.

A Wireless Mesh Network is an infrastructure system consists of broadcasting nodes planned in a interconnect topology. Wireless mesh networks consist of mesh clients, mesh routers and gateways. The mesh clients are frequently laptops, cell phones and additional wireless plans. The mesh routers transfer the data to and from the gateway which may but need not to be joined the Internet.

Ad-hoc On-Demand Distance Vector (AODV) routing is an oblivious routing protocol for mesh networks and other wireless ad-hoc networks (Dana A and Ghalavand G 2011). The same protocol is used in fuzzy logic but it performs differently on the mesh network. (Sharma S and Kumar S 2013). It is an on-demand and distance-vector routing protocol, meaning that a route is established by AODV from a destination, since AODV protocol Route Discovery is applied when a source node wishes to send a packet to the destination node.

Most of the reactive routing approaches employ full flooding schemes to discover optimal routes. In these approaches, an active source initiates a route discovery process by broadcasting a Route Request packet (RREQ) to the whole network (Luo H 2009). All nodes, except the source and the destination, are required to rebroadcast the first received RREQ’s, and/or the RREQ’s propagated from better routes. In most cases, only the intermediate nodes between the source and the destination are the candidates for the optimal routes, the nodes in far regions unnecessarily participate in the route discovery.

Routing for Wireless Mesh Networks

Wireless mesh networks seek to build a tough and high routine infrastructure to provide users invasive Internet access (Mirabedini S J and Teshnehlab M 2008). In a mesh network, each client accesses a local High speed Access Point (HAP), and multiples stationary correspondence with one another over the wireless channel and forms a Multi hop, wireless backbone for data delivery. This backbone eventually forwards user traffic to a few Gateway Access Point (GAP) that moreover connect to the wired Internet.

There are two primary challenges in routing over wireless mesh networks (Sun B and Gui C 2009). First, routing design has to address issues in both short and long-time scales. Similar to wired routing, coarse-grained course-plotting maintains stable routes in the long term. In the meantime, the fine-grained procedure has adapted to the immediate wireless channel variations. The channel unity time is typically at the scale of a few milliseconds in order to achieve high throughput.

A good wireless mesh routing algorithm has to ensure both long-term route stability and achieve short-term opportunistic performance. Second, wireless routing has to ensure strength against a wide range of soft and hard failures, ranging from transient channel outages, links with transitional loss rates, to persistent channel disconnections, nodes under Denial-of-Service (DoS) attacks, and failing nodes. The state-of-the-art solutions do not address both issues (Ma L and Denko M K 2007).

Nodes Communication in WMN

A Wireless Mesh Network (WMN) is a communication network made up of radio nodes organized in mesh topology. The coverage area of the radio nodes working as a single network is called a mesh cloud. Access to this mesh cloud, is dependent on the radio nodes working in harmony with each other to create a radio network. A mesh network is reliable and avoids redundancy.

A wireless mesh network can be seen as a special type of wireless ad-hoc network (Oliveira T and Mahadevan S 2011). It has a more planned configuration, and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. An ad-hoc network, on the other hand, is formed ad-hoc when wireless devices come within communication range of each other. The mesh routers may be mobile, and be moved according to specific demands arising in the network (Matos R and Sargento S 2012).

Node Methods: Configuring the Node

Procedures to configure an individual node can be classified into:

— Control functions

— Address and Port number management, unicast routing functions

— Agent management

— Adding neighbours

They have higher throughput gain over single path routing. Its robustness is also better than the single and multipath routing protocols.

2.1 Fuzzy Logic Routing

Based on the investigation of the traffic congestion problem for wireless mesh network, researchers described many routing protocol. In WMN, the Access Point needs not to be reached of all the nodes in the network. Nodes around the access point forward the packets from neighbour nodes to the access point. In this situation traffic may occur (Mirabedini S J and Teshnehlab M 2008). To overcome the above drawbacks, fuzzy logic algorithm was suggested to predict the failures and to guarantee efficient routing of this network. The modified Neuro fuzzy depends on the conditional shortest path routing procedure for wireless mesh network to avoid fake node and calculate network efficiency (Abedini S M and Karimi A 2012).

Fuzzy logic is used only to AP when Source S attempts to send a packet to Destination D and has no information of a route. AODV protocol oblivious route performs the maintenance of the network. Fuzzy sets or fuzzy traffic means when there is traffic the data packet are to be lost. When there is a change in the network topology, the existing routes can no longer be used. In such a scenario, the S can be used as an alternative route to the D to AP. This is called fuzzy logic on the mesh network (Zeng Y and Xiang K 2013). FL requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them.

- Fuzzification data concerns network topology and further it is divided into logic variables that are second-hand in the obtainable system of deduction.

- Inference System or Inference Engine: the logic variables coming from the fuzzification process are applied to a specified set of rules and produce a set of linguistic variables related to the inference output.

- Defuzzification: uses the linguistic variables coming from the inference system and converts them into hard values according to the defuzzification strategy being used.

The work of the fuzzification is to decide the degree of membership to an unbreakable input in a fuzzy set. The fuzzy rule base is used to present the fuzzy relationship between the input and output fuzzy variables. The output of the fuzzy rule base is determined and based on the degree of membership specified by the fuzzifier. The defuzzification is used to convert outputs of the fuzzy rule base into true values. In order to present the standard routing in mesh, the thermal field approach and fundamental fuzzy logic technique are used (Suman S and Sukhdip S 2012).

The routing protocol that has been proposed to mesh and ad-hoc networks for unique path, which means only a single route, is used between a source and a destination node. The main goal of multipath routing is to allow the use of several good paths to reach destinations, not just the best path. This should be achieved without imposing excessive control overhead in maintaining such paths. In this traffic aware routing of fuzzy logic, throughput and packet delivery provides better performance than the existing routing in the network (Maji A 2010).

The purpose of multipath routing is to use efficient data transmission using fuzzy logic. The routing protocols perform better in terms of packet delivery and incur lower routing overhead especially in the presence of high mobility.

2.2 Neuro Fuzzy based Conditional Shortest Path

To survive the congestion and delay problem in wireless network for a representative network topology many researchers have studied the problem of traffic (Chandralekha and Praffula K B 2010). After investigating the existing work carefully, it is observed that these algorithms involve high overhead AP's (TalebiFard P and Leung V 2008). In order to improve the fuzzy, Neuro fuzzy algorithm was developed. To make an efficient routing based on CSPR for wireless mesh network, a Neuro fuzzy logic routing is proposed.

The Neuro fuzzy logic performs in high level data to reach the destination. It chooses the path from distance and considering the time efficiency, network throughput, and delay in the network. The objective of the suggested algorithm is to achieve high level data transfer and to provide a Neuro fuzzy logic routing algorithm to find the shortest route from source to destination in the network. It increases the throughput performance in the network (Giri P K 2012).

A Neuro fuzzy is a hybrid system that incorporates the concept of fuzzy logic and neural networks. A fuzzy system consists of three blocks: fuzzification, fuzzy rules, and defuzzification or normalization. Each of the blocks could be designed differently. Fuzzification is supposed to convert the analog inputs into sets of fuzzy variables. For each analog input, several fuzzy variables are generated with values between 0 and 1 (Dely P, Kassler A and Bayer N 2010).

The number of fuzzy variables depends on the number of member functions in fuzzification process. Fuzzy variables are processed by fuzzy logic rules, with MIN and MAX operators. The Neuro-fuzzy system attempts to present a fuzzy system in a form of neural network. The Neuro-fuzzy system consists of four blocks: fuzzification, multiplication, summation, and division. Fuzzification block translates the input analog signals into fuzzy variables by membership functions. Then, instead of MIN operations in classic fuzzy systems, product operations are performed among fuzzy variables (Khare A and Sharma A 2011).

This Neuro-fuzzy system with product encoding is more difficult to implement, but it can generate a slightly smoother control surface (Xi N and Shen Y 2014). The summation and division layers perform defuzzification translation. The weights on upper sum unit are designed as the expecting values; while the weights on the lower sum unit. Neuro-fuzzy system architecture resembles neural networks because cells perform different functions like neurons, such as signal multiplication or division.

An efficient network congestion control has to prevent the packet losses, which are caused by unexpected traffic bursts. Thus, it has to estimate the dynamic behaviour of the traffic in the nodes buffers and send the congestion notifications to sources early enough. Therefore, due to the dynamic nature of buffer occupancy and congestion at a node, it is expected that applying a fuzzy logic control seems to be a very interesting issue (Harkous H and Makhlouta J 2011).

The overturn pathway is stored in a table in the nodes along the routing table. In hop-by-hop routing, they replaced to maintain routing tables in the middle nodes, with forwarding in sequence. The Neuro fuzzy based CSPR outperforms the existing routing algorithms (Sohan G and Payal K 2011). It always choose optimal path for routing with minimum routing overhead and make high throughput. This is accredited to the fact that Neuro-fuzzy routing model routes are most favorable and steady.

2.3 Neuro Fuzzy Scheduling based CDS

In wireless mesh network, Connected Dominating Set (CDS) based virtual backbone plays an important role for efficient routing and broadcasting. CDS is a promising approach for broadcasting. A node in the CDS consumes more energy and energy depletes quickly than non-dominating nodes. Neuro Fuzzy algorithm achieves good results in terms of the network, but network performance has to be increased and the energy level in the network has to be saved. A minimum size CDS does not necessarily guarantee the optimal network performance from energy efficient point of view (Li X, Wu J and Lin S 2012).

This type of CDS is based on priority based data transmission in the network. Existing method is used to avoid a traffic using neuro fuzzy logic for improving the network performances. The connected dominating set algorithm using NDD method in the network. The objective of this approach is to save the energy level in the network (Kim T K and Seo H S 2008).

The Connected Dominating Sets (CDS) are considered to be very efficient for broadcasting a message from one node to all the nodes in the network. They have to be implemented with the NDD method, existing CSPR routing method for shortest path on the data broadcast in the network. A CDS is a sub graph of a given undirected connected graph such that all nodes in the graph are included in the CDS or directly attached to a node in the CDS. A Minimum Connected Dominating Set (CDS) is the smallest CDS for the entire network. For a virtual backbone-based route discovery, the smaller the size of the CDS, the smaller is the number of unnecessary retransmissions (Razvan R and Deaconescu D 2009). If the RREQ packets are broadcasted using the nodes in the CDS, the minimum number of retransmissions can be acheived.

The Scheduling based Neuro Fuzzy Logic with Neighbour discovery distance method is used in AODV. The NDD method checks the priority and finds the nearby nodes in the network. CDS is used to dominating the set of nodes to collects the neighbour nodes information and send the data to destination on shortest path. It reduces the energy level on the whole network performs. Recent research has started to focus on multi-path routing protocols for load balancing.

Multipath on-demand routing protocols tend to compute multiple paths, at both the traffic sources as well as at intermediary nodes, in a single route discovery attempt. It reduces the route discovery latency and the control overhead. A route discovery is needed only when all the discovered paths fail. Spreading the traffic along several routes could alleviate congestion. Multi-path routing also provides a higher aggregate bandwidth and effective energy level based on scheduling as the data forwarding load can be send the data to all paths on network.

Link Quality Degradation

The quality of wireless links in WMNs can degrade due to severe interference from other collocated wireless networks. By switching the tuned channel of a link to other interference-free channels, local links can recover from such a link failure. They cope with heterogeneous channel availability: Links in some areas may not be able to access wireless channels during a certain time period due to spectrum etiquette or regulation. For example, some links in a WMN need to vacate current channels if channels are being used for emergency response by the wireless links (Aggarwal N and Gaur D 2013).

The scheduling fuzzy logic is associated with dominating set technique during the process (Gupta I and Riordan D 2005). Connected Dominating Set (CDS) plays a significant position in wireless mesh network for capable routing and broadcasting (De Miranda Rios V and de Castro Monteiro C). CDS move towards for distribution. A node in the CDS consumes more energy and the power depletes rapidly than non dominating nodes. In wireless mesh system using fuzzy logic one can improve the accuracy and certainties of removing the traffic in the field. A Neuro Fuzzy scheduling based CDS and NDD (Neighbour discovery distance) method on the wireless mesh network can be presented.

The routine of this scheduler is calculated using NS-2 and evaluated in conditions of quantitative events such as pathway achievement ratio, average end-to-end delay, throughput but have to add an energy parameter on this network. All the parameters are to take comparison of the network level, Scheduling based data transmission, priority based data sending and receiving process and then RREQ and RREP are an important progress in this AODV protocol model. NDD method collects the entire neighbour node considering the AP in order to set the high priority node in the network (Khaled S and Khalil I 2013).

Connected Dominating Sets

The data are being sent by wireless mesh network from source (S) to destination (D) on network topology. Access point collects the neighbour node list and connected dominating nodes to transmit the data to destination. It works intermediately from source to destination on network. AP has together the data sending and receiving process in the network. The traffic conditions to be checked on Access Point. If there is any traffic in the network, it intimates to the AP (karimi A and Abedini S M 2013).

The Scheduling based Neuro Fuzzy logic is used to set the minimum number of connected set to the destination in the network. It saves the energy and shortest path route discovery in the network. It reduces the packet’s delay and reduces energy model on their wireless mesh network (Milanes V and Alonso J 2011). The connected set is more efficient and scalable on that time of the network process. If scheduling based Neuro Fuzzy-set logic is applied in some conditions, the data loss can be retrieved from the source to destination process (Lertsuwanakul L and Unger H 2011). When data are being sent from source to destination, the network saves the energy and then reduces the traffic and quickly sends the data from source to destination in the network.

An ad-hoc network uses the route discovery process to find the path between source and destination. In this source node initiates the route discovery when it has no route to the destination. It broadcasts a Route Request packet (RREQ) to its neighbours. Each receiving node in turn broadcasts RREQ packet. This process is repeated until the packet reaches the destination and then destination node will send the Route Reply message (RREP) to the source (Dely P 2010).

This type of route discovery leads to broadcast storm problem. To overcome this problem, the dynamic CDS nodes can be used during the route discovery process in AODV. When a CDS node receives a RREQ packet, it broadcasts the packet. The non-CDS are not rebroadcasting the RREQ packets. Thus the number of RREQ packet transmission is reduced and the network congestion is avoided. To take advantage of transmissions that reach nodes other than the next-hop, a novel mechanism called priority-based forwarding is introduced. Priority-based forwarding maximizes the progress each packet makes by choosing the node closest to the destination to forward the packet.

Scope of this work is to improve the route discovery using Neighbour discovery distance method and CDS path. It works on hop to hop data transmission on network. In wireless mesh network, using a Neuro fuzzy logic based CDS chooses an optimal path for data transmission on network. If there is any jamming in the network, Neighbour discovery distance (NDD) method identifies the nearby nodes on network using CDS for high priority node on neighbour model. This type of CDS is the priority based data transmission in the networks.

2.4 Energy Efficient Dynamic Connected Dominating Set with Multi-Point Relay

Many algorithms have been analyzed and implemented to reduce the high energy consumption and degradation of network performance. Further, to improve the performance and Scalability of the network a novel Energy efficient Neuro fuzzy logic algorithm has been implemented. It improves the data transmission and save the energy level in the network (Dora L 2010).

The energy efficient neuro fuzzy logic method has to take different parameters for performance throughput, average end-to-end delay, packet delivery and energy level. To have an Energy Efficient Based data transmission in the network the dynamic connected dominating set with MPR is used. A connected dominating set is based on multipoint relays (Elisangela S A and Billy A P 2014). The only facts assumed for a given node is two hop neighbourhoods and the list of neighbours that have selected the node as multipoint relay such neighbours is called multipoint relay selectors. In wireless mesh network the Energy efficient Neuro fuzzy logic is adapted to improve the data transmission and save the energy in the network (Kassar M and Kervella B 2008).

This information can be contained in packets that nodes periodically broadcast to their neighbour in order to monitor links validity. They have to use routing information and neighbour node information, collection algorithms are also used (Kaur K and Goyal S 2011). These assumptions make the algorithm very attractive for mobile ad-hoc networks since it needs just local updates at each detected topology change. To carry out data transfer from source to destination in the network intermediately they have to dynamically change the CDS path and use the MPR.

It is used for a number of purposes, including bandwidth aggregation, minimizing end-to-end delay, increasing fault-tolerance, enhancing reliability, load balancing, and so on. The idea of using multiple paths has existed for some time and it has been explored in different areas of networking. In the traditional circuit-switching network, alternate path routing was used to decrease the probability of call blocking.

In Energy Efficient Neuro Fuzzy based CDS and MPR method, the node saves the energy and reduces the energy expenditure level. The CDS changes the place from one to another in the network (Kunarak S and Suleesathira R 2008). Multi point relay is used to intermediate data diffusion in the network, it most significant and secure statistics processing on the scheme. The network which saves the energy model is the most essential model of the system. This set of connections has to take parameters for achievement ratio, standard end-to-end stoppage, throughput and spending of energy model. All the parameters are taken for the judgment of the network level and the liveliness level. In MPR data communication data sending and receiving process is a main concern.

Wireless devices are generally battery-limited, energy consumption for the execution of estimation, learning, and decision making algorithms should be minimized. Therefore, lightweight protocols would be required to implement cognitive radio networks. Again, cognitive radio components in each node can cooperate to improve the efficiency of frequency usage due to the fact that some nodes might be unable to observe the environment accurately. With cooperative cognitive radio, the information obtained from observation and knowledge gained from a learning algorithm can be exchanged and shared among wireless nodes.

The distance-energy efficiency for the first hop in a wireless ad-hoc network with randomly distributed nodes as consider the snapshot at the time of the first-hop transmission, even if a Multi hop transmission is subsequently required for the packet to reach its ultimate destination. The first-hop distance-energy efficiency is defined as the ratio of the average progress of a packet during its first transmission and the energy consumption of that transmission.

As any intermediate relay transmission can be viewed as a new first-hop transmission for the remaining route, the first-hop distance-energy efficiency should be consistent with the overall distance-energy efficiency of the entire route in a homogeneous environment. Scope of this work is to provide energy efficient neuro fuzzy based dynamic CDS with multipoint point relay. It takes low energy consumption for data transfer on Multipoint relay node to increase the throughput level and reduce the network delay.

CHAPTER 3

IMPLEMENTATION OF FUZZY LOGIC ROUTING FOR WIRELESS MESH NETWORK

3.1 Introduction

To make routing decisions based on more than one check, buffer residency, node energy and hop count and to provide an efficient routing method for wireless mesh network, a fuzzy logic based routing is proposed. Simulation results in NS-2 verify that they perform better than multiple restriction routing. The AP is not necessary to reach each and every node in the network (Ortiz A M and Royo F 2011). Nodes around the AP forward the packets from the neighbour nodes to the AP. If there significant number of nodes in the network, neighbour nodes can transfer data with the AP in a few hop. The wireless mesh network uses oblivious fuzzy logic routing to perform high level data to reach the destination. If any traffic occurs in this network it's to be cleared and data to be sent efficiently in the network (Chouhan S and Gaikwad R B 2013).

Fuzzy Logic Routing

The fuzzy logic routing algorithm is used to provide the optimal best case performance on all possible traffic demands faced by users. The goal is to minimize the maximum traffic aware of oblivious intrusion sets in the network (Singh T P and Das V 2012). The fuzzy logic routing method is shown in figure 3.1.

It is a maiden attempt that investigates the fuzzy logical oblivious routing issue in the context of wireless mesh networks. The fuzzy logic based oblivious routing solution can effectively perform in the dynamic for wireless mesh network routing.

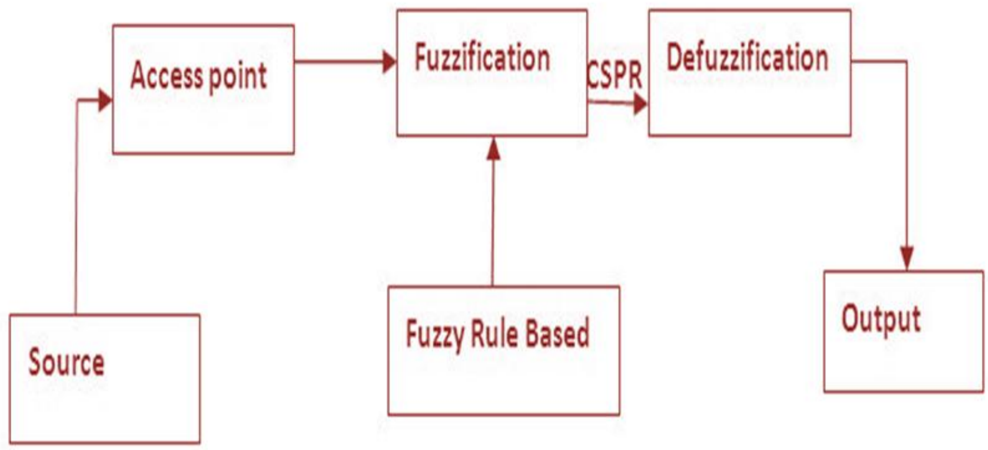

Figure 3.1: Fuzzy Logic Routing Method

Wireless mesh networks have many logical functions in the network which has been gaining increasing attention and is used as a high-performance and low-cost resolution to last broadband internet access (Kumar D and Aseri T C 2010). In a wireless mesh network, local access points and stationary wireless mesh routers communicate with each other and form a backbone structure which forwards the attacks between mobile clients and the Internet. Simulate existing Oblivious Routing (OBR), Oracle Routing (OR), and Shortest-Path Routing (SPR) strategies follow similar configuration as in the fuzzy logic based routing on wireless mesh network (Ramakrishnan M 2012). This Fuzzy logic based routing, works on access point to send the data from source to destination in the network.

During this process it minimizes the packet loss compared to the OR which loses many data and doesn’t resolve. In fuzzy logic based shortest path routing (SPR) protocol average conditional intermeeting time is taken as link costs rather than standard intermeeting time and messages are routed over the network. Comparison is made between fuzzy logic based SPR protocols with the existing shortest path (SP) based routing protocol through real trace-driven simulations. The results demonstrate that fuzzy logic based SPR achieves higher delivery rate and lower end-to-end delay compared to the shortest path based routing protocols. The conditional intermeeting time represents internode link cost and makes effective forwarding decisions while routing a message (Mamoun M H and Barrak S 2013). Routing algorithms utilize a paradigm called store-carry-and-forward. It generates the multiple messages from a random source node to a random destination node at each second.

The concepts of AODV that makes it attractive for MANETs with limited bandwidth include the following:

Minimal Space Difficulty: The algorithm makes sure the nodes that are not in the active path do not keep information about this route (Shehu A and Maraj A 2012). A node receives the route information and sets a reverse path in its routing table and propagates the RREQ to its neighbours. If it does not receive any RREP from its neighbours for this request, it deletes the direction-finding information that it has recorded.

Simple: It is simple with each node behaves as a router, maintaining a simple routing table, and the source node initiating path discovery asks for making the network self-starting.

The performance ratio of fuzzy logic routing is better than oblivious routing (Singhrova A and Prakash N 2007). The ratio generally remains in the range, high on the other performance, with irregular conditions in the network.

The fuzzy logic routing strategy performs competitively against the oracle routing strategy even without the knowledge of attack based demand on this wireless network. The main advantage of this work is to maximize the performance level and minimize the data loss.

Single Path Routing

During the route discovery, forward path and reverse path are to be considered. According to the way of protocol to record these paths, two different approaches are considered. The list of hops traversed is stored in the messages directly. In source routing, more overhead is added to data packets, as the entire route must be specified in the packet header. In Hop-by-hop routing, the reverse path is stored in a table (routing table) in the nodes. In this routing, packet overhead is replaced by routing tables in the intermediate nodes, with forwarding information (Sharma M and Khola R K 2011). AODV is based on hop-by-hop routing and it maintains routing table entries at intermediate nodes to forward traffic.

Multi Path Routing

Most of the routing protocols that have been proposed for mesh and ad-hoc networks are unique paths, which mean only a single route is used between source and destination node. The main goal of multi path routing is to allow the use of several paths to reach destination, not just the best path. This should be achieved without imposing excessive control overhead in maintaining such paths.

The accessibility of multiple paths between source and destination is used to achieve the benefit of fault tolerance (Shakti K and Brahmjit S 2013). The forms of introducing fault tolerance at the routing level in mesh network are by introducing redundancy in the network or providing backup routes to be used when there is a failure. To this end, some techniques may be applied like packet salvaging, which consists of modifying the route of packet if the actual route is broken.

3.2 Fuzzy Logic Routing Algorithm

```
If S message D received then
    Source A from neighbour list
    Compute the network topology
If source (p) = T (Traffic) then
        Reset parent (A <= Received)
        Reset Data
Broadcast FUZZY-LOGIC message
Enter neighbour discovery phase
    End if
  End if
If CSPR message AP received then
If source (p) = D (Destination) then
   Reset parent (p <= Received)
   Packet received
Broadcast FUZZY-SET logic
Enter Route discovery
      Else
```

If $P =$ loss then

Broadcast FUZZY-Operator logic

End if

End if

End if

If $P \neq$ loss then

Broadcast set Defuzzification Logic

End if

Various steps involved in the Fuzzy Logic protocol

1. The data are sent by wireless mesh network from source (S) to destination (D) on this network topology.

2. Source node collects the neighbour node list and it transmits the data to destination intermediately through AP (Access Point).

3. APs work together when data sending and receiving process is carried out in the network. The traffic conditions are to be checked at this access point.

4. Fuzzy logic can be applied on this level to the AP and if there is any traffic on this Network path it will select alternate shortest path route to send the data. It mainly works on conditional shortest path routing in the network.

5. It is the more secured method because it is reduces the packet's delay and number of loss packets in this wireless mesh network. The fuzzification works properly at this time of the traffic.

6. If Fuzzy-set logic is applied in some conditions, the data loss can be retrieved from C++ file.

7. If fuzzy operator is executed when the packet loss occurs. Otherwise the defuzzification process is executed.

When data are sent from source to destination, the network finds the shortest path and checks the traffic for data transfer.

3.3 Results and Discussions

The goal of simulation is to analyze the behaviour of the fuzzy logic AODV by deploying wireless mesh networks. The simulation environment is created in NS-2, a network simulator that support for simulating mesh wireless networks. NS-2 was written using C++ language and it uses the Object Oriented Tool Command Language (OTCL). It came as an extension of Tool Command Language (TCL). The simulation was carried out using a MESH environment consisting of 71 wireless mobile nodes roaming over a simulation area of 1200 meters x 1200 meters flat space operating for 10 seconds of simulation time. The radio and IEEE 802.11 MAC layer models are used. Nodes in simulation move according to the Random Waypoint mobility model, which is in the random direction with maximum speed from 0 m/s to 20 m/s. A free space propagation channel is assumed for the simulation. Hence, the simulation experiments do not account for the overhead produced when a multicast member leaves a group.

Multicast sources can start and stop the sending packets. Each packet has a constant size of 512 bytes. Each mobile node in the network starts from a random location to a random destination with a randomly chosen speed. In an IEEE 802.11 based wireless mesh network, there are significant problems in maintaining fairness and low delay for long-hop flows. Express forwarding, which has been used to the IEEE 802.11 Task Group, is a possible strategy for solving these problems.

In this system consists of well-organized tree construction scheme that manages to decrease data overhead compared to customary ad-hoc routing protocols. To do that, it takes full advantage of the broadcast the nature of the wireless medium. It expands the routing protocol with group association functionalities well-matched with those currently used in the Internet, to allow for the deployment of solution in existing networks with current equipments. In addition, use an auto-configuration protocol which provides nodes with topologically correct IP addresses and reduces system overhead by the use of prefix permanence. All wireless routers using the same internet gateway for configured with addresses on the same prefix. Limitation and experimental results show that scheme is able to offer a good performance, while being fully well-suited with standardized multicast solutions of their mesh networks.

Network throughput Performance

Throughput is the ratio of successful packet delivery and minimum packet delay over a network. The throughput performance of oblivious routing and the fuzzy logic routing is depicted in figure 3.2. The performance of fuzzy logic routing throughput level is higher than oblivious routing in the network.

It calculates the performance of throughput level and high accuracy of the data transferring from source to destination in the network. The higher performance is due to the fuzzy logic engine's intelligent technique for discriminating packet loss by wireless induced errors.

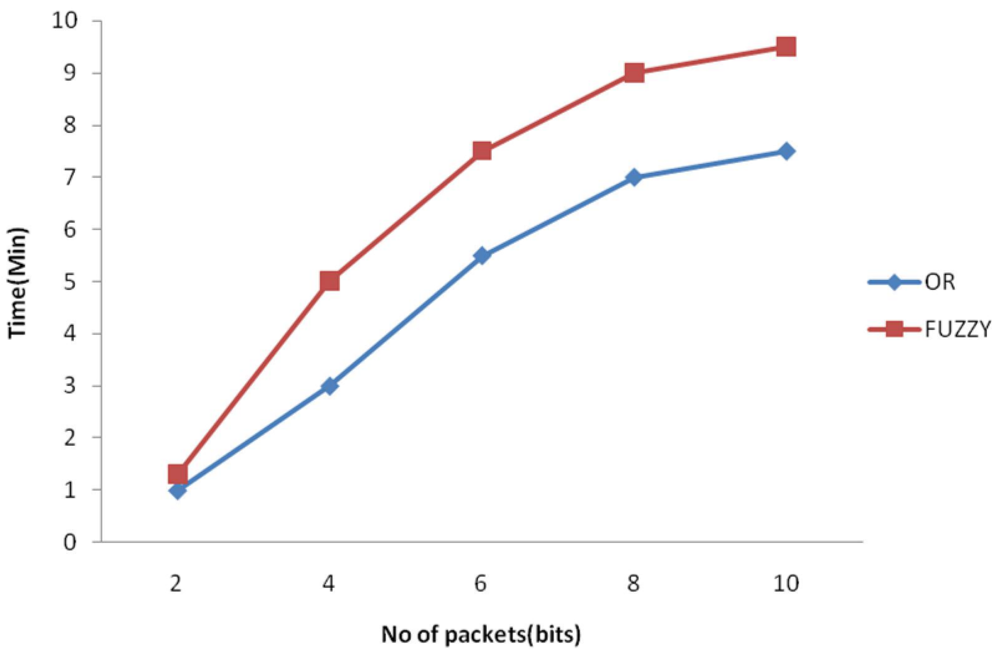

Figure 3.2: Throughput Performance of Fuzzy Logic

A wireless routing protocol has a maximum probability of packet delivery and minimum probability of data loss in the network. In wireless networks the attempt has always been to calculate the packet dropped, and delay of the data transmission in the network performed. If they have any packets to be dropped, there will be delay in the network.

The delay performance on the whole network is measured. A new model is used to investigate the use of fuzzy logic theory for assisting the routing error detection mechanism in an ad-hoc network.

Packet Delivery ratio model

Packet delivery ratio calculates the data transmission between the source node and destination node in the network. Fuzzy Logic has been used for routing and management of an ad-hoc wireless network. The fuzzy logic routing algorithm takes into account of input variables, such as delay, throughput and energy consumption. It differentiates performance between the existing and fuzzy logic routing in the network. It states the number of packets sent and received during the data transmission and intermediately shows the difference in calculating the time taken by packets to reach the destination.

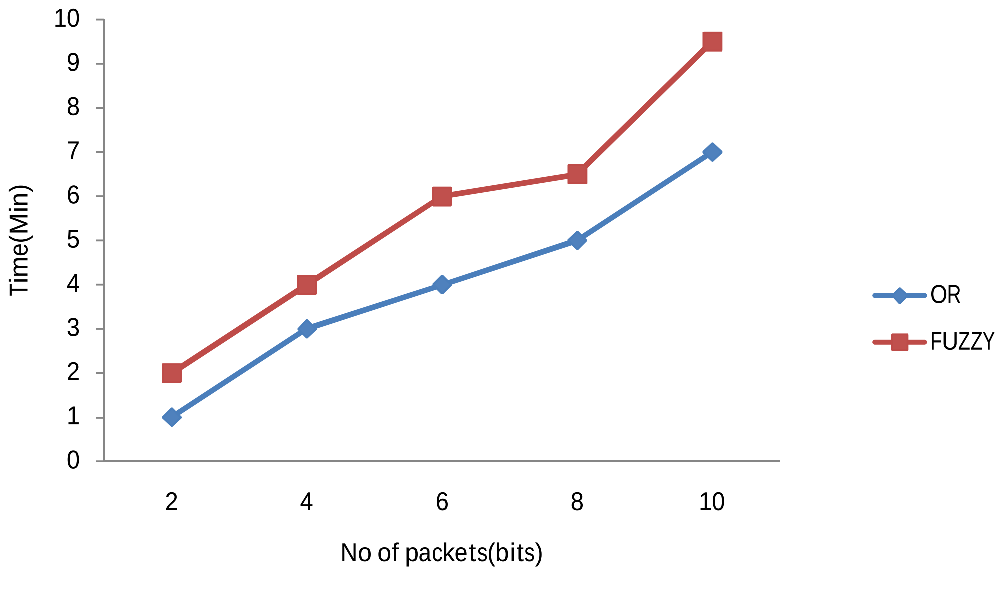

Figure 3.3: Packet delivery Performance of Fuzzy Logic

The performance of packet delivery ratio for the fuzzy routing protocol is depicted in figure 3.3. The optimal performance in the network is guaranteed a controlled randomized routing strategy which can be viewed as cost of exploration. The cost of exploration is proportional to the total number of packets whose route deviates from the optimal path. If the number of delivered packets increase sub linearly, the packet exploration cost of the delivered packet increases. It represents the number of control packets divided by the total number of received data packets.

Packet delivery fraction is the ratio of data packets delivered to the destination and those generated by the sources. It is calculated by successful delivered packets and number of packets originated from the source.

$$\mathbf{PDF = (Pr/Ps)*100}$$

Where, Pr is total Packet received & Ps is the total Packet sent.

End-to-End Delay

End-to-End delay includes all possible delay caused by buffer during route discovery latency, queuing at the interface, retransmission delay at the MAC, propagation and transfer time. It is defined as the time taken for a data packet to be transmitted over a wireless mesh network from source to destination.

End-to-End delay is written as

$$\mathbf{D = (Tr - Ts)}$$

Where, Tr is receive Time and Ts is sent Time.

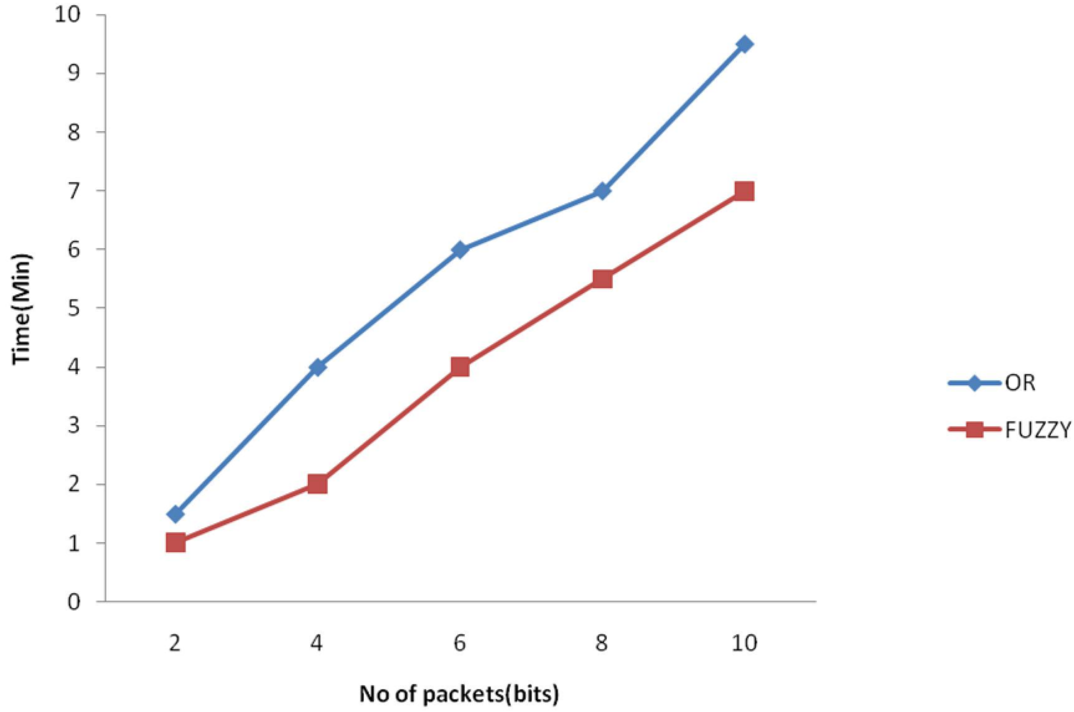

Figure 3.4: Delay Performance of Fuzzy Logic

The performance of delay for the proposed routing protocol and oblivious routing(OR) protocol is depicted in figure 3.4. Delay is used to calculate the packet dropping level of network. If data is dropped, the time taken by fuzzy logic routing is very low but oblivious routing delays to send and receive the data processing in the networks. The route discovery process can take some time and this delay can be increased due to problems in the medium access, such as busy channel and collisions.

3.4 Conclusion

The performance evaluation of fuzzy logic controller was done by the use of network simulator-2. The simulation results prove that the fuzzy logic controller performance specifications belong to the existing one of oblivious routing. In this traffic aware routing of fuzzy logic, throughput and packet delivery ratio provide better performance than the existing routing method in the network. The ratio generally remains in the range of occasional spikes. In the existing oblivious routing packets delay over lapped hence the fuzzy logic based conditional shortest path routing method was used. Fuzzy logic controller was implemented to find the path to transfer the data from source to destination easily and efficiently.

CHAPTER 4

IMPLEMENTATION OF NEURO FUZZY ROUTING FOR WIRELESS MESH NETWORK

4.1 Introduction

In wireless mesh networks many routing protocols are used for conditional shortest path routing like AODV, by considering only the shortest route to destination. The data transfer in wireless mesh networks is to and from the AP and these protocols congest the routes and overloaded AP's. Therefore there is a need to reduce the congestion and to avoid traffic to improve the network performance on the system.

The major problem lies in routing, such as traffic, delay and low network performance (Saraswala P P 2013). To make an efficient routing based on CSPR for wireless mesh network, a Neuro fuzzy logic routing is proposed.

Neuro fuzzy logic performs on high level data to reach the destination. This one chooses the path from distance based on time efficiency, network throughput, and delay in the network. Simulation results in NS-2 verify that they perform better than modified fuzzy logic routing.

4.2 Neuro Fuzzy Routing

A source node S needs a route to some destination D and it broadcasts a route request message to its neighbours, including the last known sequence number for that destination. When the route is busy in a controlled manner through the network, the route request message waits till it reaches a node that has a route to the destination. Each node forwards the route request and creates a reverse route for itself back to node S (Saiful A and Anwar F 2009). When route request reaches the D**,** that node generates a route reply that contains the number of hops necessary to reach D and the sequence number for D. Each node participates in forwarding this back toward the originator of the request route (node S) and creates a forward route to D.

The performance ratio of Neuro fuzzy routing is better than fuzzy routing. The ratio generally remains in the range, high on the other performance, with irregular conditions in the network. The result shows that Neuro fuzzy routing strategy performs competitively against the existing routing strategy. The neuro fuzzy logic routing provides high performance and low data loss.

Adaptive control and Neuro fuzzy control are the two advanced methods for time-varying and non-linear processes. This course will begin with adaptive control of linear systems, nonlinear systems and related control issues. Neural network and fuzzy model will be described as general structures for approximating non-linear functions and dynamic processes. The neuro fuzzy system structure is shown in figure 4.1.

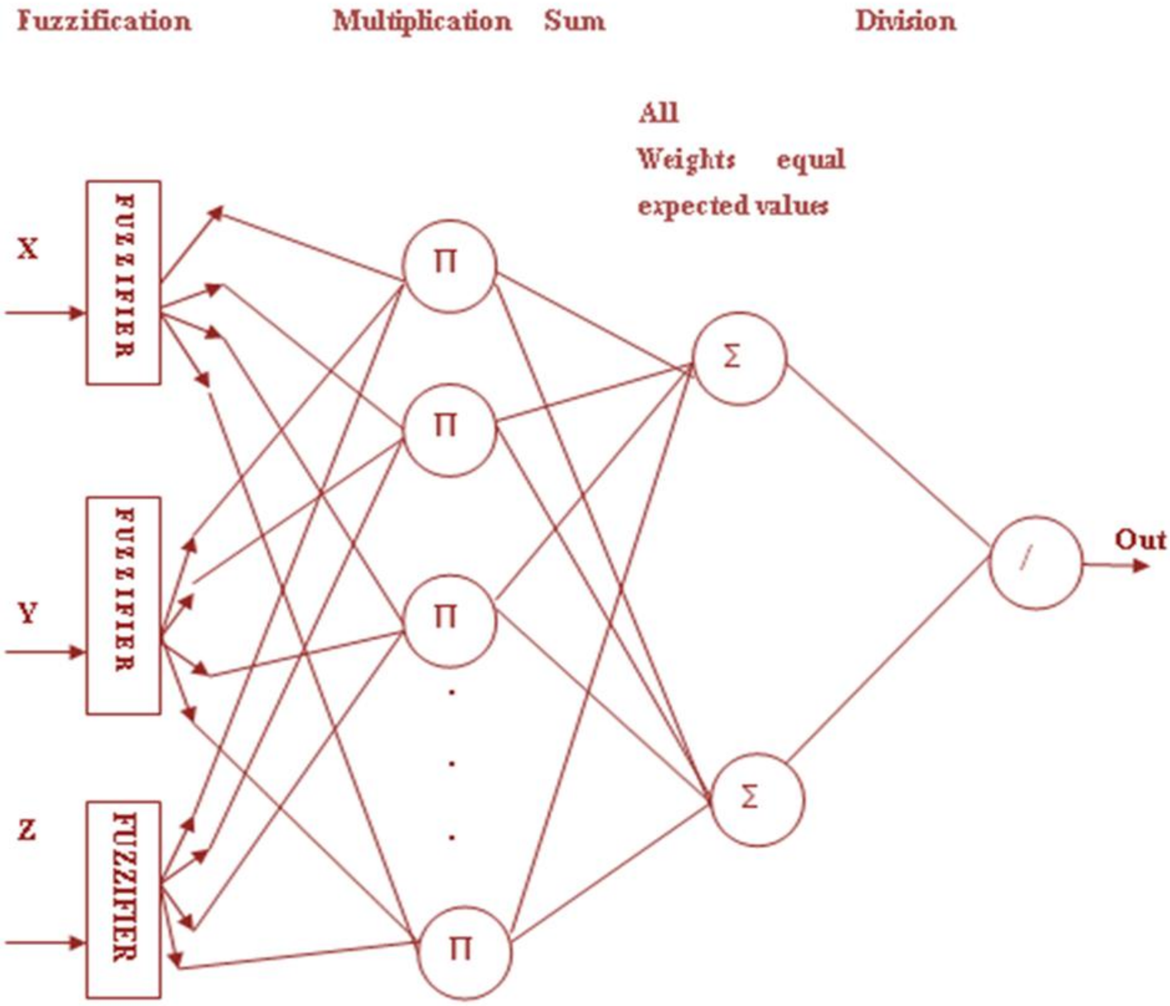

Figure 4.1: Neuro Fuzzy System

Based on the comparison of these methods, Neuro fuzzy model will be proposed as a promising technology for adaptive control of non-linear processes (Omari M 2012).

Conditional shortest path routing

It is the intermeeting time between two nodes given that one of the node has previously met a certain other node. This updated definition of intermeeting time is also more convenient for the context of message routing because the messages are received from a node and sent to another node on the way towards the destination. Here, conditional intermeeting time represents the period over which the node holds the message (Santhosh Baboo S and Narasimhan B 2009).

To show the benefits of this metric, a conditional shortest path routing (CSPR) protocol is proposed in which average conditional intermeeting times are used as link costs rather than standard intermeeting times and the messages are routed over conditional shortest paths (CSP). Comparison can be made between CSPR protocol and the existing shortest path (SP) based routing protocol through real trace-driven simulations. The results demonstrate that CSPR achieves higher delivery rate and lower end-to-end delay compared to the shortest path based routing protocols. This shows how well the conditional intermeeting time represents internodes link costs and helps making effective forwarding decisions while routing a message. The Conditional Shortest Path Routing (CSPR) protocol routes the messages over conditional shortest paths and their cost of links between nodes is defined by conditional intermeeting times rather than the conventional intermeeting times.

Considering that the current queue length of a node is around the half of the queue size and the rate changing of the queue length in an increasing phase, the queue will be filled in the near future. Hence, congestion may occur, and future arrival packets may be dropped. To prevent congestion, the incoming flow rate should be immediately decreased.

In the other case, when the current queue length of a node is close to zero and the rate changing of the queue length in a decreasing phase, then the flow rate should be increased to optimize fully the utilization of radio resources and to maximize fully the overall throughput of the wireless network.

In Conditional Shortest Path algorithm, the dimension capacities for each end-to-end connection request pair uniformly and provide topological shortest paths for the pair. At routing time, the connections stay within their topological shortest path, which is a union of all links in the pair and use their own dimensioned resources and introduce minimal interference with other connection pairs. If the shortest available path found for a request uses links outside of CSPR, the connection uses the resource of other pairs. If the network load is low, the connection gets accepted as other resources are often free. If the network load is high, this connection gets rejected since it can block other connections with higher probability.

Fuzzy traffic adaptation model

An efficient network congestion control has to prevent the packets losses, which are caused by unexpected traffic bursts. Thus, it has to estimate the dynamic behaviour of the traffic in the nodes buffer and send the congestion notifications early enough to the source. Therefore, due to the dynamic nature of buffer occupancy and congestion at node, applying a fuzzy logic control seems to be a very interesting issue.

The proposed model is conceived as a non-linear controller in which the input-output relationship can be expressed by using small number of linguistic rules or relational expressions (Kalpana G and Punithavalli M 2013).

The goal of proposal is to make control decisions based on the instantaneous queue length and the variation rate of the queue length at each wireless node. By monitoring the rate of changes in queue length (variation rate) in addition to the queue length, the model is able to provide a measure of queue state, by using explicit rate congestion notifications.

A simple and effective protocol called Agent assisted Fuzzy-Cost based Multi-objective QoS multicast Routing protocol for MANETs builds a low cost multicast tree with bandwidth constraint. It proposes various objectives as follows. (i) Maximizing packet delivery fraction (ii) minimizing end-to-end delay (iii) maximizing the route life time (iv) minimizing the transmission cost of multicast tree. Several QoS metrics are considered for buffer occupancy rate. The remaining battery power of a node is described as the minimum amount of battery power available on any node along the path. The available battery power and the required power level of a node for transmission are taken into account to find the remaining battery power of a node.

The Routing Unit performs evaluation of suggested paths using the given input from the connection request, the current network conditions and the policy, based on linguistic rules. A single metric called route potentiality that expresses the suitability of a path for a set of constraints is introduced. The fuzzy part of the routing unit calculates the potentiality of each available route. The output of the routing unit will result after all possible routes are evaluated or when a route is evaluated as good enough, in terms of evaluation function becoming greater than a threshold. The next hops evaluate the chosen domains forming the spanning tree of connectivity between current domain and destination domain.

4.3 Neuro Fuzzy Logic Routing Algorithm

```
If S message D received then
    Source A from neighbour list
    Compute the network topology
If source (p) =T (Traffic) then
        Reset parent ( A <= Received)
        Reset Data
Broadcast NEURO FUZZY-LOGIC message
If (check=N)
{ Available paths on Route
  Data Transfer from Source
Else
  Enter neighbour discovery phase
End if
}
End if
If CSPR message AP received then
Data transfer
If source (p) = D (Destination) then
    Reset parent ( p <= Received)
Packet received
Broadcast NEURO FUZZY-SET logic
Enter total neighbour Route discovery
      Else
If P =loss then
Broadcast NEURO FUZZY-Operator logic
    End if
```

End if

End if

If P ≠ loss then

Broadcast set Defuzzification Logic

End if

Steps in Neuro Fuzzy Logic Method

Step1: The data are sent by wireless mesh network from source (S) to destination (D), the source node collects the neighbour node list.

Step 2: Then it transmits the data to destination intermediately through AP (Access Point).

Step 3: AP has to gather the data, sending and receiving process in the network.

Step 4: The traffic conditions to be checked on Access Point.

Step 5: The Neuro Fuzzy logic can be applied on this level to the AP.

Step 6: If there any traffic occurred in Network path, the Neuro fuzzy logic will select alternate route to send the data. It mainly works on conditional shortest path routing in its function in the network.

Step 7: It is the more secured method because it reduces the packet's delay and number of loss packets in wireless mesh network. The fuzzification works properly at the time of traffic.

Step 8: Neuro Fuzzy-set logic is applied to some conditions retrieved from C++ file, when data loss occurs. It discovers the available neighbour route.

Step 9: Neuro fuzzy operator executes the packets.

Step 10: At that time defuzzification is also executed only if there is no packet loss.

4.4 Results and Discussions

The radio and IEEE 802.11 MAC layer models are used in neuro fuzzy method. Nodes in our simulation move according to the random way point mobility model, which is in the random direction with maximum speed from 0 m/s to 20 m/s. A free space propagation channel is assumed for the simulation. Hence, the simulation experiments do not account for the overhead produced when a multicast member leaves a group. Multicast sources can start and stop the sending packets. Each packet has a constant size of 1024 KB.

Each mobile node in the network starts from a random location to a random destination with a randomly chosen speed. In an IEEE 802.11 based wireless mesh network there are significant problems in maintaining fairness and low delay for long-hop flows. Express forwarding, which has been proposed to the IEEE 802.11 Task Group, is a possible strategy for solving these problems.

The neuro fuzzy system consists of well-organized tree a construction scheme that manages to decrease data overhead compared to customary ad-hoc routing protocols. To do that, it takes full advantage of the broadcast nature of the wireless medium.

In addition, use an auto-configuration protocol which provides nodes with topologically correct IP addresses and reduces system overhead by the use of prefix permanence. That is, all wireless routers using the same internet gateway are configured with addresses on the same prefix. The experimental result shows that this scheme can offer a good performance, while being fully well-suited with standardized multicast solutions of their mesh networks.

The simulation scenario is designed specifically to assess the impact of network concentration on the performance of the protocols. The impact of network density is assessed by deploying 30 –71 nodes over a fixed square topology area of 1500 m x 1500 m using 20m/s node speed and 3 identical source-destination connections. The parameter values for simulation are shown in table 4.1.

Table 4.1: Values for NF-AODV Simulation

Parameters	**Value**
Version	NS-all in one 2.28
Protocols	NF-AODV
Area	1500m x 1500m
Transmission Range	250 m
Traffic model	UDP,CBR
Packet size	1024 KB

Throughput Performance

Throughput is the ratio of successful packet delivery and minimum packet delay over a network. It improves the network performance by maximize the packet delivery and minimize the packet delay of the network.

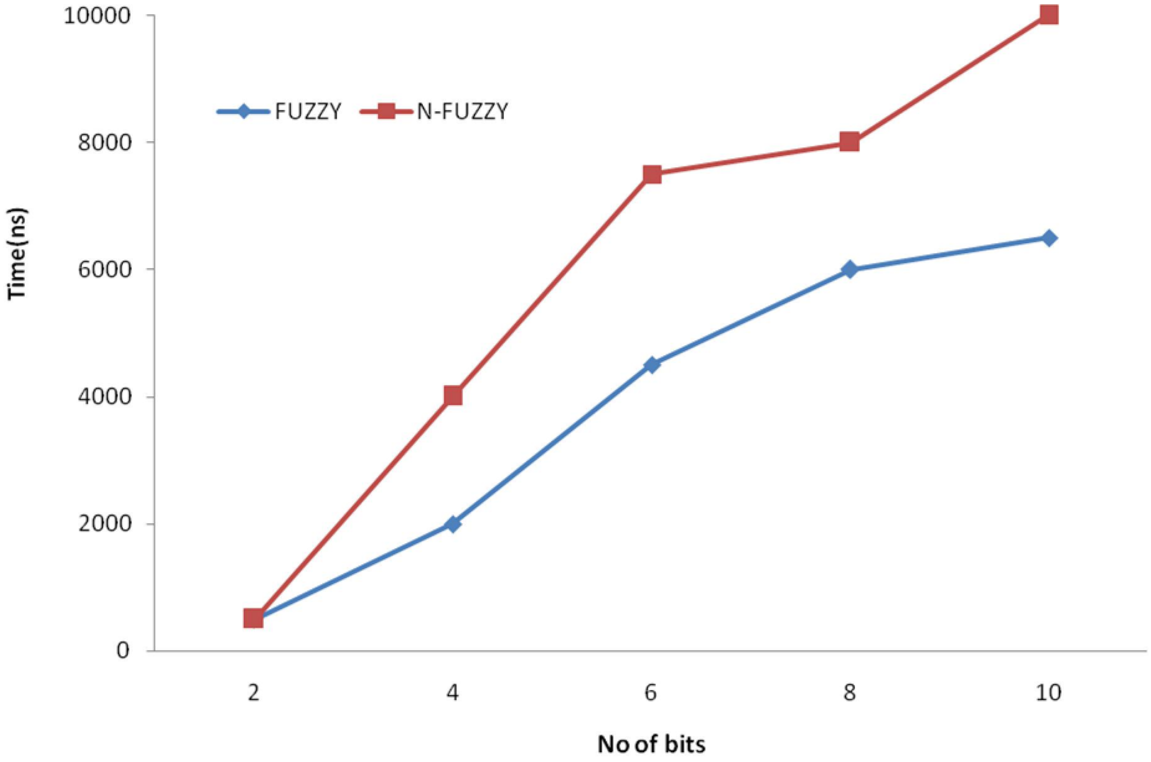

Figure 4.2: Throughput Performance of Neuro Fuzzy Logic

The throughput performance of the fuzzy routing and the neuro fuzzy logic routing is depicted in figure 4.2. The Neuro fuzzy logic routing throughput level was higher than fuzzy routing in the network.

It calculated the performance of throughput and high accuracy of the data transferring on source to destination of the network. The higher performance is due to the Neuro-fuzzy logic engine is presented as an intelligent technique for discriminating packet loss by wireless induced errors.

Packet Delivery Fraction

Packet delivery fraction is the ratio of data packets delivered to the destination and those generated by the source. It is calculated by dividing the number of packet received in the destination divided by the number of packet originated from the source in the network.

$$\mathbf{PDF = (Pr/Ps)*100}$$

Where, **PDF** is packet delivery fraction
Pr is total Packet received &**Ps** is the total Packet send.

Packet delivery is calculating the data transmission between the one to another node of the network. The performance of the packet delivery fraction for the proposed routing and the fuzzy routing is depicted in figure 4.3. Fuzzy Logic has been used for routing and management of an ad-hoc wireless network. The Neuro fuzzy logic routing algorithm takes into account of input variables, such as delay, throughput and energy consumption. It differentiates performance between the existing and Neuro fuzzy performance in the network. It states number of packets are sent and received during the data transmission and intermediately shows the difference in calculating the time taken by packets to reach the destination.

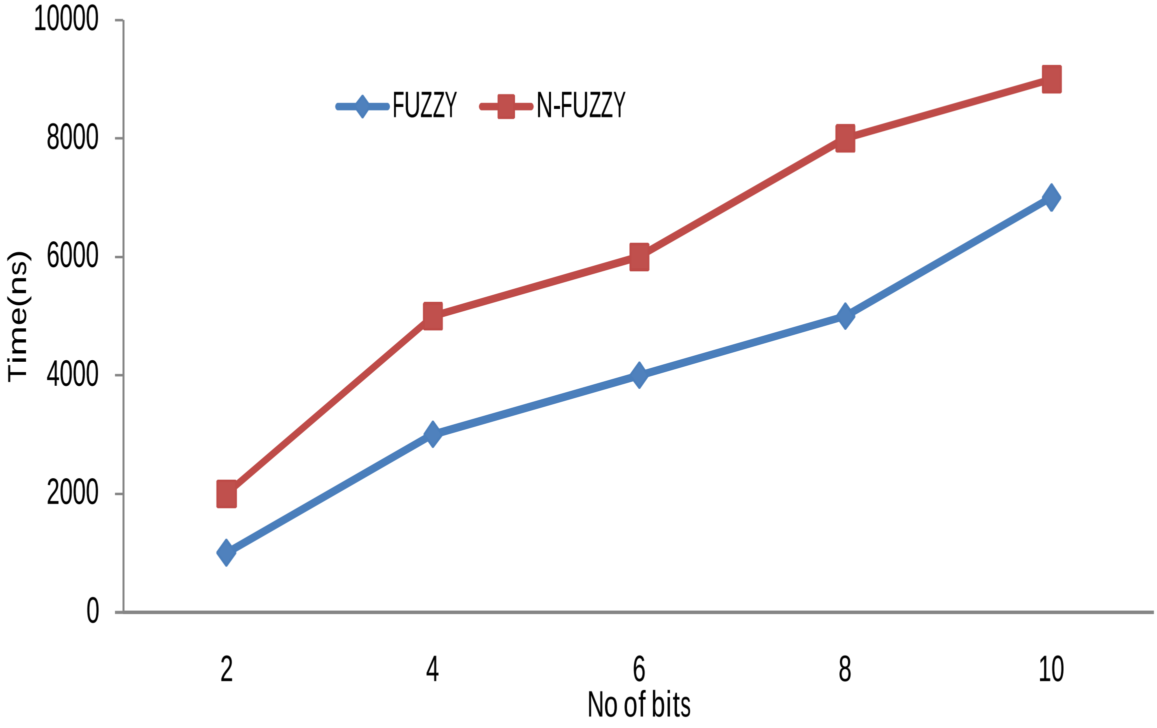

Figure 4.3: Packet Delivery Performance of Neuro Fuzzy Logic

End-to-End Delay

End-to-End delay includes all possible delay caused by buffer during route discover latency, queuing at the interface queue, retransmission delay at the MAC, propagation and transfer time. It is defined as time taken for a data packet to be transmitted across a MESH network from source to destination. Average end-to-end delay is written as

$$\mathbf{D = (Tr - Ts)}$$

Where, **D** is delay, **Tr** is receive Time and **Ts** is sent Time.

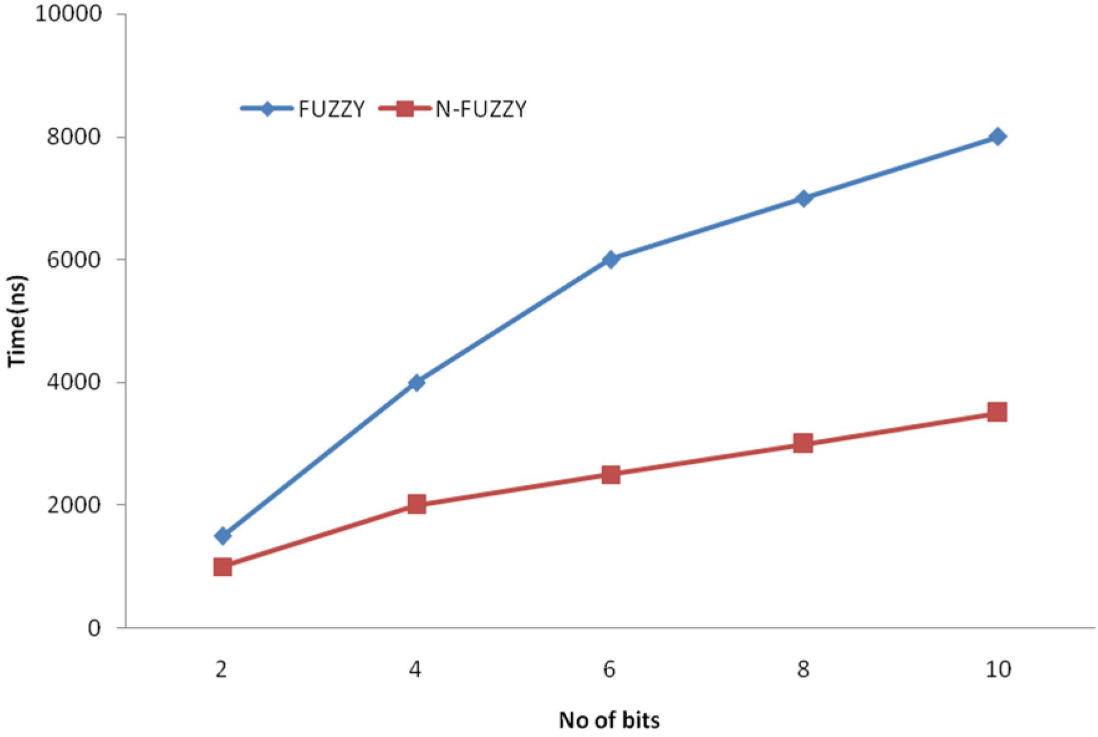

Figure 4.4: Delay Performance of Neuro Fuzzy Logic

The performance of delay for the proposed routing protocol with the fuzzy routing and also a comparison of delay for different nodes routing protocol is depicted in figure 4.4. Delay is used to calculate the packet dropping level of the networks and if data are dropped, the time taken by Neuro fuzzy logic routing is very low but fuzzy logic routing delays to send and receive the data processing in the networks. The route discovery process can take some time and delay can be increased due to problems in the medium access, such as busy channel and collisions. If they have any problem in transmitting data to the route, Neuro fuzzy logic is discovering the neighbour node to get active and send the data quickly compared to fuzzy logic routing which delays its process.

4.5 Conclusion

Wireless mesh networks are becoming a promising selection for last mile internet access as their initial infrastructure cost was low. One of the most important factors influencing performance of WMN is the routing protocol used. To maximize the performance of wireless mesh network neuro fuzzy based routing was proposed. The simulation result showed that this neuro fuzzy based CSPR outperforms the existing routing algorithms. It always chooses the optimal path for routing with minimum routing overhead and maximize the throughput. This is attributed to the fact that Neuro-fuzzy routing produces routes that are optimal and stable.

CHAPTER 5

IMPLEMENTATION OF NEURO FUZZY SCHEDULING BASED CONNECTED DOMINATING SET IN WIRELESS MESH NETWORK

5.1 Introduction

Neuro fuzzy logic method is taken in wireless mesh network to increase a network performance. Comparison must be made between the fuzzy logic routing and neuro fuzzy logic scheduling based CDS method on the process. A Connected Dominating Set (CDS) based virtual backbone plays an important role in wireless mesh network for efficient routing and broadcasting. A CDS is a promising approach for broadcasting. A node in the CDS consumes more energy and the energy depletes quickly than non dominating nodes. Although previous conditional shortest path routing algorithms achieve good results in terms of the network, one has to increase a network performance and to reduce the energy level in the network.

A minimum size CDS does not necessarily guarantee an optimal network performance from an energy efficient point of view (Santhi G and Nachiappan 2013). The data transfer takes place from source to destination in the network. The Neighbour discovery distance (NDD) method is used to identify the nearby nodes on network using CDS. The CDS provides high priority node on neighbour model. This type of CDS is used for priority based data transmission in the networks. This method is used to avoid traffic and improve the network performances on the system (Sakthidharan G R and Chitra S 2013).

The most efficient routing method for wireless mesh network is Neuro fuzzy scheduling based conditional shortest path routing method on the process. Here Connected dominating set construction algorithm uses the NDD method in the network. The Simulation results in NS-2 verify that they perform better than multiple restriction routing. The AP need not to be in the reach of all the nodes in the network. Nodes around the AP forward the packets from the neighbour nodes to the AP. The SNF routing protocol improves the network performance and reduces the energy level on network.

Priority based data transmission

The priority based data transmission on the high priority node with NDD and their delay constraints drive the selection of optimal transmission strategies at the different layers hop-by-hop. In order to realize the mentioned priority in (Pushpalakshmi R and Vincent A K 2011) queuing framework for data transmission process in the network, defining information feed back to a node for a connected dominating set priority model on this algorithm is required.

Mobility Management Model

A WMN must manage the mobility of user nodes throughout the network. As they move, user devices change their point of attachment to the network, connecting to the access point with the strongest signal. Mobility raises several issues, similar to those known in both wired and cellular networks. Mobility management has been integrated into the routing process in order to cope with highly mobile nodes (Parimal K G 2012). In wired and cellular networks, routing and mobility management have been defined separately although they are complementary mechanisms.

Neuro Fuzzy Logic Method

In a network like WMN, the various constraints like collisions, traffic level, buffer occupancy, energy level need to be considered. It is not enough if only one constraint is considered. This is because of the complex relationship existing between the different constraints. Multi-constrained routing is to resolve their complete problem and does not have solution. It is required to use various heuristics and soft computing techniques to solve them. Using the routing algorithm for neighbour discovery distance method to set a priority based data transmission in the network is recommended besides using an AODV routing protocol with connected dominating set constraints on the data pre processing model. The neuro fuzzy scheduling based CDS is chosen for the best result on network, so all data transmissions are secured and they reduce the data loss in the network.

Implementation of Routing Model

In the SNF model, one has to implement an AODV routing protocol used in ad-hoc networks. In AODV, each node maintains a routing table which is used to store destination and next hop IP addresses as well as destination sequence numbers. Each entry in the routing table has a destination address, next hop, precursor nodes list, lifetime and distance to destination. It is simple with each node behaving as a router, maintaining a simple routing table, and the source node initiating route discover request, making self-starting the network.

5.2 Scheduling Neuro Fuzzy

The AODV with Scheduling based Neuro Fuzzy Logic with Neighbour discovery distance method is used for checking a priority and nearby nodes in the network. CDS is applied to dominate the set of nodes and collect the neighbour nodes information and send the data to destination on shortest path and reduce the energy level on their whole network performance. Recent research does focus on multi-path routing protocols for load balancing. Multipath on-demand routing protocols tend to compute multiple paths, at the traffic sources as well as at the intermediary nodes, in a single route discovery attempt (Radunovic B 2010). This reduces both the routes discover latency and the control overhead as a route discover is needed only when all the discovered paths fail. Spreading the traffic along several routes could alleviate congestion. Multi-path routing also provides a higher aggregate bandwidth and effective energy level based on scheduling as the data forwarding load can send the data to all paths on network.

Neighbour Distance Discovery technique

The Neighbour Distance Discovery (NDD) method is used to send the information quickly and to rectify low latency of the network transmission on the process. This method is for broadcasting in the network. The new scheme minimizes the traffic by location information and limits broadcast retransmission only to host near the node coverage in the network (Ortiz A M and Olivares T 2012).

Each broadcasting node attaches the list of selected forwarding nodes to the message before broadcasting it. So that the NDD method improves the performance of the resources and energy level of the network latency.

Connected Dominating Sets

Using a Connected Dominating Sets (CDS) is considered to be very efficient for broadcasting a message from one node to all the nodes in the network. One has to implement the NDD method. A CDS is a sub graph of a given undirected connected graph such that all nodes in the graph are included in the CDS or directly attached to a node in the CDS. A Minimum connected dominating set is the smallest CDS for the entire network. For a virtual backbone-based route discover, smaller the size of CDS used, the smaller is the number of unnecessary retransmissions. RREQ packets of a broadcast route discover process get forwarded only by the nodes in the CDS for minimum number of retransmissions.

Connected dominating set forwarding rule

A node retransmits if it has not already received the packet in the connected dominating set. On the other hand, the multipoint relay technique has been proposed to optimize flooding at the time of last hop information. The idea behind this technique is to compute some kind of local dominating sets. Each node computes a multipoint relay set with the following properties:

• The multipoint relay set is included in the neighbourhood of the node. The elements of the multipoint relay set are called multipoint relays (or MPR for short) of the node.

• Each two-hop neighbour of the node has a neighbour in the multipoint relay set. Some multipoint relay covers the two hop neighbour.

5.3 Dominating Set based Routing

Assume that a CDS has been determined for a given ad-hoc network. Dominating-set based routing usually consists of three steps:

1. If the source is not a gateway host, it forwards the packets to a source gateway, which is one of the adjacent gateway hosts in its absorbent set.

2. This source gateway acts as a new source to route the packets in the induced graph generated from the connected dominating set.

3. Eventually, the packets reach a destination gateway, which is either the destination host itself or a gateway in the dominating neighbour set of the destination host.

Priority based Data transmission

To take advantage of transmissions that reach nodes other than the next-hop, a novel mechanism called priority-based forwarding is introduced. Priority based forwarding maximizes the progress. Each packet makes by choosing the node closest to the destination to forward the packet. Different priorities are realized by using priority-based timers: the node with highest priority performs forwarding first, and other nodes hearing the transmission automatically cancel their transmissions, thereby minimizing the number of duplicate transmissions in a cheap and distributed way.

5.4 SNF-Connected Dominating Set Algorithm

S-Source, D-Destination, T-Traffic, P-Packets, M-message, CD-Connected Dominating, R-Route, F-priority

Step 1: Initialize network nodes

Initialize the packet counter function

Send S message to D

Step 2: If (M=true)

S sends Packets to D

Step 3: if Else (M=false)

Get T on Network Path

Step 4: Message dropped on network

Using NDD method

Step 5: Broadcast scheduling NEURO FUSSY-SET logic

Enter total neighbour Route discovery

Step6: Check if (F=0)

Check the Neighbour list and connected set node

Goto First Priority Node on CDS Path

Step 7: if Else ($F \neq 0$)

Preprocess of Priority model

Else

Waiting on network model

End

Step 8: Check Available Route & Energy to Save on CDS Path

Step 9: R=0&&T=0;

Step 10: P send to S to D normally

Packets sending to Destination

Else

End

Step 11: Drop the Packets *P*

Exit

Step 12: Every Time update Route information

Implementation of the SNF-Connected Dominating Sets routing algorithm working steps

1. The data are sent by wireless mesh network from source (S) to destination (D) on network topology.

2. Access point collects the neighbour node list and connected dominating nodes to transmit the data to destination intermediately from source to destination on network.

3. AP has to gather the data sending and receiving process in the network. The traffic conditions need to be checked on access point. If there is any traffic in the network, it is intimated to the AP.

4. The scheduling based neuro fuzzy logic is used to set the minimum number of connected set to the destination in the network. It saves more energy and finds shortest path route in the network.

5. It reduces the packet's delay and reduces the energy level on their wireless mesh network. The connected set is more efficient and scalable network on that time of network process.

6. The scheduling based neuro fuzzy-set logic applies some conditions when there is the data loss and it can be retrieved from the source to destination process.

7. Using a new route processing model in the network and then connected dominating set routing algorithm for processing method in the network.

8. When data are being sent from source to destination, the network saves the energy, reduces the traffic and quickly sends the data from source to destination in the network.

5.5 Results and Discussions

The platform used was the NS-2 (Network Simulator version 2). NS-2 is a discrete event simulator targeted at networking research. NS-2 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless networks. The simulation environment is created in NS-2, a network simulator that provides support for simulating mesh wireless networks. NS-2 was written using C++ language and it uses the Object Oriented Tool Command Language (OTCL). It came as an extension of Tool Command Language (TCL). Fuzzy Routing Decision was implemented using the Fuzzy Logic.

The simulator executed with various input configuration settings and the statistics collected were analyzed in comparison with other well-known on demand routing protocol AODV. This simulation modeled a network of nodes placed randomly within 1200 × 1200 meter area. Each node had a radio propagation range of 250 meters and channel capacity. Two-way propagation model was used. The IEEE 802.11 distributed coordination function was used as the medium access control protocol.

A random waypoint mobility model was used in SNF model. Each node randomly selected a position and moves toward that location with a speed ranging from just above 0 m/s to 20 m/s. When the node reached that position, it became stationary for a programmable pause time; then it has selected another position and repeat the process. The simulation was repeated with different start values. Neuro Fuzzy logic Based Connected Dominating Set Routing Algorithm with a Multiclass Scheme for generator was developed to simulate CBR (Constant Bit Rate) sources. The radio and IEEE 802.11 MAC layer models were used. The size of the data payload was 512 bytes. Data sessions with randomly selected sources and destinations were simulated. Each source transmitted data packets at a minimum rate of packets to send the source to destination in the network. Traffic classes were randomly assigned and simulation was carried out with different bandwidth requirements. There were no network partitions throughout the simulation. Each simulation was executed for 600 seconds of simulation time. The parameter values for simulation are shown in table 5.1.

Table 5.1: Parameters for SNF-AODV Simulation

Parameters	**Value**
Version	Ns-all in one 2.28
Protocols	SNF-AODV
Propagation model	Free Space
Area	1500m x 1500m
Transmission Range	250 m
Traffic model	UDP,CBR
Packet size	1024 KB
Mobility Model	Random Way Point
Node’s Mobility	0-100m/sec

Throughput Performance

Each protocol has different average throughput levels. The average throughput of scheduling Neuro fuzzy routing outperforms AODV and traffic balancing as it is always choosing the optimal path.

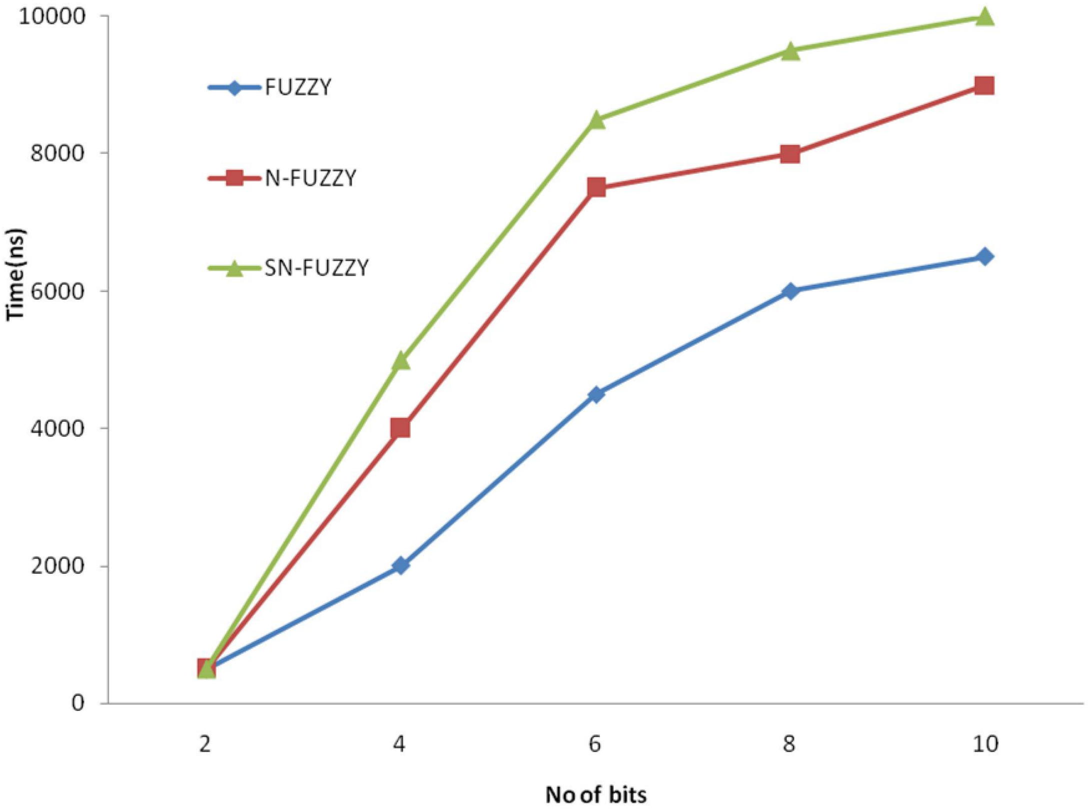

Figure 5.1 Throughput Performance of SNF-AODV

Throughput is the ratio of successful packet delivery and minimum packet delay over a network. The throughput performance of Neuro Fuzzy and the Scheduling Neuro fuzzy logic routing is depicted in figure 5.1.

The performance of Scheduling Neuro fuzzy logic based Connected Dominating sets routing throughput level was higher than neuro fuzzy logic routing in the network. The performance of throughput level and high accuracy of the data transfer from source to destination in the network was calculated.

Packet Delivery Fraction

Packet delivery fraction is the ratio of data packets delivered to the destination and those generated by the source. It is calculated by dividing the number of packet received in the destination by number packet originated from the source.

$$PDF = (Pr/Ps)*100$$

Where, Pr is total Packet received & Ps is the total Packet sent.

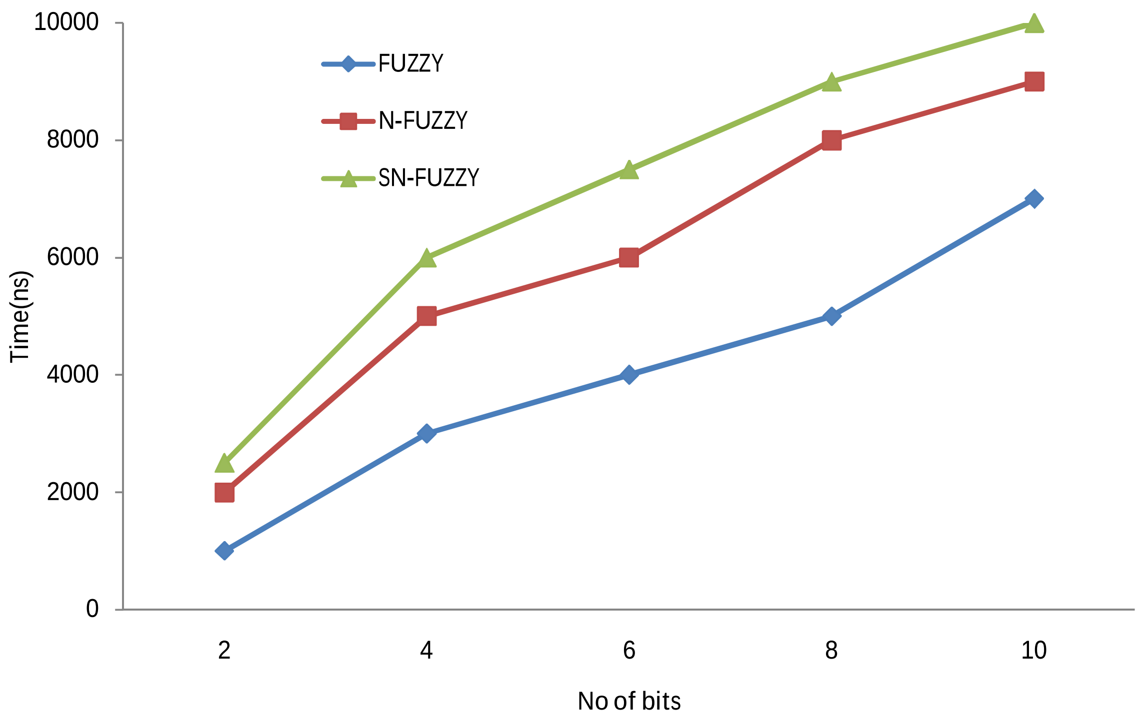

Figure 5.2 Packet Delivery Performance of SNF-AODV

Packet delivery fraction calculates the data transmission between the one to another node in the network. The performance of packet delivery fraction for the SNF routing is depicted in figure 5.2. The scheduling Neuro fuzzy logic used the optimal routing. Fuzzy Logic has been used for routing and management of an ad-hoc wireless network. The fuzzy logic routing algorithm takes into account of input variables, such as delay, throughput and energy consumption. The Neuro fuzzy routing might have more routing overhead because of measuring lots of constraints at each node on the path. It has the least overhead due to routing. It is true that a lot of time is spent initially for setting up of the route. But fuzzy routing always leads to stable routes and the routes are used for a longer period.

End-to-End Delay

Average end-to-end delay included all possible delay caused by buffer during route discovery latency, queuing at the interface queue, retransmission delay at the MAC, propagation and transfer time. It is defined as time taken for a data packet to be transmitted across a MESH network from source to destination. Average end-to-end delay is written as

$$\mathbf{D = (Tr - Ts)}$$

Where, Tr is receive Time and Ts is sent Time.

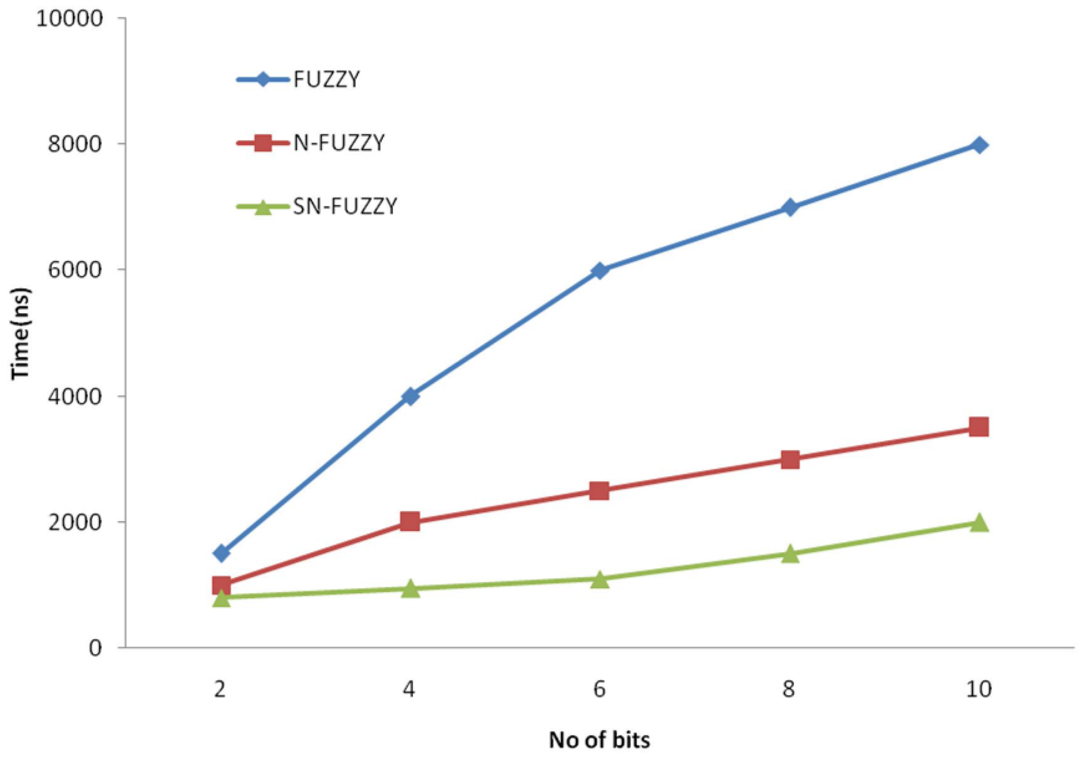

Figure 5.3 Delay Performance of SNF-AODV

The performance of delay for the SNF routing protocol and also a comparison of delay for different routing algorithm is depicted in figure 5.3. Delay is used to calculate the packet dropping level of the network and if the data are dropped, the time taken by scheduling neuro fuzzy logic routing is very low in the network.

5.6 Conclusion

Fuzzy logic routing in wireless mesh network improved the handling of accuracy and removed the traffic. A Neuro Fuzzy scheduling based CDS and NDD method are presented on the wireless mesh network. The performance of this scheduler was studied using NS-2 and evaluated in terms of quantitative measures such as path success ratio, average end-to-end delay, and throughput. The Scheduling data transmissions are priority based data sending and receiving process. It is an important process on this AODV protocol model. The simulation shows that the approach is efficient, promising and applicable in ad-hoc wireless mesh network.

CHAPTER 6

IMPLEMENTATION OF ENERGY EFFICIENT NEURO FUZZY BASED DYNAMIC CONNECTED DOMINATING SET WITH MULTI POINT RELAY IN WIRELESS MESH NETWORK

6.1 Introduction

In wireless mesh network the Energy Efficient Neuro fuzzy logic method is applied to increase the network performance. It is already discussed a Neuro fuzzy and scheduling based routing on network but one has to take an energy efficient based data transmission in the network using the dynamic connected dominating set with MPR. The connected dominating set is based on multipoint relays. The only knowledge assumed for a given node is two hop neighbourhoods and the list of neighbours that have selected the node as multipoint relay and such neighbour are called multipoint relay selectors. This information can be contained in hello packets that nodes periodically broadcast to their neighbour in order to monitor links validity.

Routing information and neighbour node information collection algorithms are used (Makhlouta J and Harkous H 2011). These assumptions make the algorithm very attractive for mobile ad-hoc networks since it needs just local updates at each detected topology change. To carry out the data transfer from source to destination in the network one has to dynamically change the CDS path and intermediately use the MPR.

The multipoint relay set is included in the neighbourhood of the node and the elements of the multipoint relay set are called multipoint relays or MPR for short. Each two-hop neighbour of the node has a neighbour in the multipoint relay set. Some multipoint relay covers the two hop neighbour. It is used for quick data transmission and identifies the nearby node on the source node. The parameters such as throughput, delivery ratio, network delay are already taken, and one has to implement an energy level parameter on network. The proposed network energy level is better than the existing model as the former has low energy consumption in the network.

Efficient Routing Information

Quality of Service Routing (QoSR) is a key function for the transmission and distribution of digitized information across networks (Ortiz A M and Olivares T 2011). It has two main objectives: finding routes that satisfy the QoSR constraints and making efficient resource utilization. Unfortunately, several factors can cause poor performance. So many problems still exist such as data loss because of overloaded incoming and outgoing message buffers, packet delay or expiration when residing in large queue or when using unsuitable routes(Ormond O and Muntean 2011). The complexity in QoS routing comes from multiple criteria, which often make the routing problem intractable.

Despite the efforts made to alleviate this issue, there still exist a number of barriers to the widespread deployment of real-time applications. The most prominent one is how to ensure the traffic adaptation in the case of heavy congestion. It is important to note that the existing solutions developed for wired networks cannot be deployed directly within WMNs.

Difficulties with these models lie in the fact that they are not adapted to different node states and resource variation as in mesh environments. The available bandwidth for each node varies with time since the medium is shared.

Routing Information on Data Transmission

In a WMN, mesh routers relay traffics on behalf of clients or other routers and this forms a wireless multi-hop network. Most WMNs are based on IEEE 802.11 commodity hardware. The performance of such WMNs can be low. One reason is the inefficient handling of small packets by the IEEE 802.11 MAC layer. The transmission time of 100 byte packet sent at 54 Mbit/s consists of 95% of overhead created by the IEEE 802.11 MAC layer. For WMNs it is consequently important to transmit small packets in an efficient way (Narasimhan B and Padmapriya R S 2013). One possibility to increase the efficiency is packet aggregation.

Energy Aware Metrics (Routing)

The majority of energy efficient routing protocols for MANET try to reduce energy consumption by means of an energy efficient routing metric, used in routing table computation instead of the minimum-hop metric. This way, a routing protocol can easily introduce energy efficiency in its packet forwarding (Anand M and Anand U 2011). These protocols try either to route data through the path with maximum energy bottleneck or minimize the end-to-end transmission energy for packets, or a weighted combination of both. The first approach for energy-efficient routing is known as MTPR (Minimum Transmission Power Routing).

This mechanism uses a simple energy metric, represented by the total energy consumed to forward the information along the route. This way, MTPR reduces the overall transmission power consumed per packet, but it does not directly affect the lifetime of each node because it does not take into account the available energy of network nodes.

The transmission energy differs from shortest-hop routing if nodes can adjust transmission power levels, so that multiple short hops are more advantageous from an energy point of view than a single long hop.

Taking different energy efficient routing protocols

The protocols select the path consuming the minimum energy. The advantage is that each transmission of a packet from its source to its destination minimizes the energy consumed. For example, a more sophisticated protocol where the selected path minimizes the additional energy dissipated by the routing of new flow, taking into account the energy lost in interferences (Obula Reddy B G and Ussenaiah M 2013). Such protocols always use the same nodes (those minimizing the energy consumed) without any consideration on their residual energy. Consequently, these nodes will exhaust their battery more quickly than the others and the network lifetime is not maximized.

The hybrid protocols selecting the path with the minimum cost, where the cost takes into account the residual energy of each visited node (neighbours) and the energy consumption of a packet on this path. These protocols avoid the problems encountered by the factors used in the cost computation. Routing protocols for mobile ad-hoc networks have different features. Regarding the way to exchange routing information, the main difference is between reactive and proactive routing protocols.

A reactive (or on-demand) routing protocol determines routes only when there is any data to send. If a route is unknown the source node initiates a search to find one and it is primarily interested in finding any route to a destination, not necessarily the optimal route.

Consumption of Energy Efficient

Broad range of applications like disaster management (systematically sensitive zone), security and military have stimulated the importance in WN during past few years. Sensor nodes are characteristically proficient of wireless communication and are considerably obliged in the amount of existing resources such as energy (power), storage (memory) and computation (Shafigh A and Kamran A 2011). These forces make the deployment and operation of WN significantly distinct from existing wireless networks, and demand the development of resource aware protocols and supervision techniques.

Route Discover using Dynamic CDS

On demand routing protocols like AODV, DSR for ad-hoc networks use route discovery process to find the path between source and destination. The source node initiates the route discover when it has no route to the destination. It broadcasts a route request packet (RREQ) to its neighbours. Each receiving node in turn broadcasts RREQ packet. This process is repeated until the packet reaches the destination and the destination node will send the route reply message (RREP) to the source. This type of route discovery leads to broadcast storm problem. To overcome this problem, the route discovery process in AODV is implemented using the dynamic CDS nodes only. When a CDS node receives a RREQ packet, it broadcasts the packet. The non-CDS does not rebroadcast the RREQ packets. Thus the number of RREQ packet transmission is reduced and the network congestion is avoided.

Energy Efficient Neuro Fuzzy

The EENF model uses an energy efficient neuro fuzzy and multipoint relays which avoid selecting the border nodes as the forwarding nodes. The architecture of multi point relay network is shown in figure 6.1.They use power adaptive broadcasting by reducing the transmission range of mobile nodes to save energy. The range buffer based approach is used to further enhance the stability of the forwarding nodes (Obula Reddy B G and Ussenaiah M 2012). The algorithm determines stable connected dominating set based node velocities. Their algorithm prefers slow moving nodes with lower velocity rather than the usual approach of preferring nodes with a larger number of uncovered neighbours. Comparison is made between this method and another one which is based on node degree. A minimum size CDS does not necessarily guarantee the optimal network performance from an energy efficient point of view. This motivates one to construct an energy efficient stable connected dominating set construction to prolong the network lifetime.

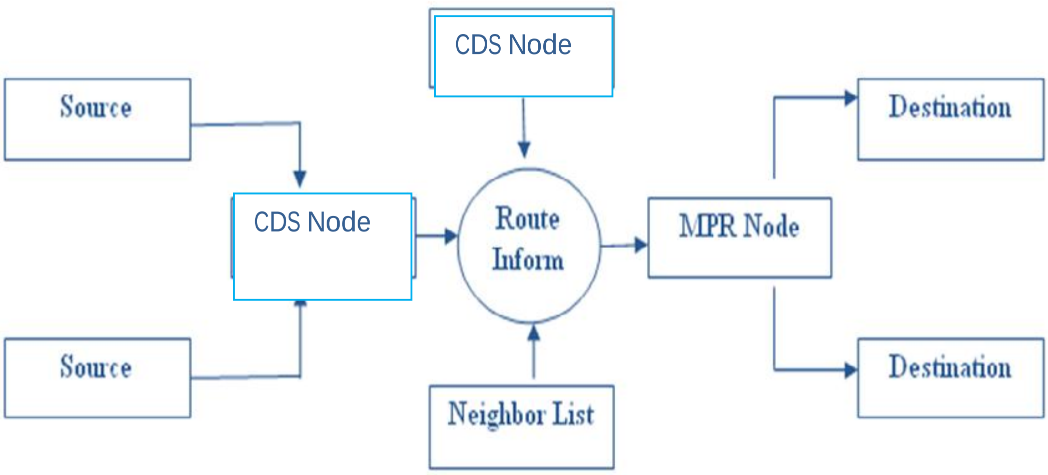

Figure 6.1: Multi Point Relay Method

Consumption Energy Level

All these protocols strive to reduce power consumption either at node level or in the network in general. All proposed solutions have a kind of trade-off that let go to have conspicuous energy saving. The following is considered as major performance demands for all the protocol: the number of routes established during route discovery, the message overheads, the cost of performing the data packet transmission and reception by different nodes, average energy conserved, data packet delivery ratio, the network throughput, the end-to-end data packet delay, computational complexity of the algorithm and finally, the network life which has a direct relationship with energy conservation.

EENF-CDS based Multipoint Relay Algorithm

S-Source, D-Destination, T-Traffic, P-Packets, M-message,
CD-Connected Dominating, R-Routing Information, MP-Multipoint Relay,
U-uncovered Node, E-Energy

Step 1: Initialize network nodes
Initialize the Topology level
Send S message to D

Step 2: If (M=true)
S sends Packets to D

Step 3: if Else (M=false)
Get T on Network Path

Step 4: Message send using MP
S collects the R

Step 5: Routing Information Saved in the network
Shortest route on Path

Step6: Check if (MP=0)

Goto First Priority Node on CDS Path

CDS Change dynamically in the network

Step 7: if Else (F≠0)

Preprocess of Priority model

Else

Waiting on network request

End

Step 8: Check Available Route otherwise

Step 9: Node's are sleep mode in the network

Step 10: Save E on Network

Step 11: P send to S to D normally

Packets sending to Destination

Else

End

Step 12: Drop the Packets *P*

Exit

Step 13: Every Time update Routing information on network

Update Routing Table information Algorithm

X, Y are nodes, channel = I,

Step 1: for i ← 0 to num. of time on node x do

Step 2: for y ← 0 to num. of time on node y do

Step 3: if (channel(x) (i) = channel(y) (j)) then

Channel-id ← channel(x) (i)

Step 4: nodes x and y lookup the route, and update routing table with new channel- Id;

Implementation of the EENF- Dynamic Connected Dominating Sets routing algorithm working steps:

1. The data are sent by wireless mesh network from source (S) to destination (D) on network topology.

2. Access point collects the neighbour node list and routing information and then dynamic connected dominating nodes to transmit the data to destination intermediately from source to destination on network.

3. AP has to gather the data sending and receiving process in the network. The traffic conditions to be checked on Access Point. If there is any traffic in the network, it intimates to the AP.

4. The Multi Point Relay nodes collect the information data from source to destination and quickly send the data transmission in the network process. Its consecutive work flow in the network is followed.

5. It reduces the packets delay and reduces energy model on their wireless mesh network. To save the rest of the data transmission time they have to save the energy model in the network.

6. The connected path spends the energy only at the time of data transmission from source to destination in the network otherwise it saves the energy level of the network.

7. Using the new routing process model in the network and then connected dominating routing algorithm for a processing method in the network.

8. If the throughput and delivery ratio is high, the energy in the network is reduced. It is the most important model in the network.

6.2 Results and Discussions

A network simulator is used to check the performance of good result in the network. The platform used was the NS-2 (Network Simulator version 2). NS-2 is a discrete event simulator targeted at networking research. NS2 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless networks. The simulation environment is created in NS-2, a network simulator that provides support for simulating mesh wireless networks. NS-2 was written using C++ language and it uses the Object Oriented Tool Command Language (OTCL). It has been used to get a graph results in the network. It came as an extension of Tool Command Language (TCL).

Dynamic CDS based Energy Efficient Based Fuzzy Routing Decision was implemented using the Fuzzy Logic. The simulator with various input configuration settings and the statistics collected were analyzed in comparison with other well-known on demand routing protocol AODV. Our simulation modeled a network of nodes placed randomly within 1500 × 1500 meter area. Each node had a radio propagation range of 250 meters and channel capacity. Two-way propagation model was used. The IEEE 802.11 distributed coordination function was used as the medium access control protocol. If all network topology to be set at the MAC based data representation on the progress.

It describes the no. of nodes included in the CDS to act as broadcast relay nodes. The average number of nodes included in the CDS with different mobility values 5m/s, 15m/s and 25m/s. The results show that CDS generated by our algorithm is larger than the values. The average size of the CDS increases with network density. The radio and IEEE 802.11 MAC layer models were used. The size of the data payload was 512 bytes. Data sessions with randomly selected sources and destinations were simulated. Each source transmitted data packets at a minimum rate of packets to send the source to destination in the network. Traffic classes were randomly assigned and simulation was carried out with different bandwidth requirements. There were no network partitions throughout the simulation. Each simulation was executed for 600 seconds of simulation time.

6.3 ENF-AODV Metrics

Wireless mesh network was designed using a different movement topology. The energy model of nodes in the network is covered over a fixed topology area of 1500m x 1500m using dynamic connected dominating set for source-destination connections. Metrics to evaluating the performance is shown in table 6.1.

Table 6.1: Metrics to evaluate the performance of EENF-AODV

S.No	No. of Node	Protocol	Throughput	Average Delay	PDF	Energy
1.	61	F-AODV	0.29	11.01	98.00	30joule
2.	61	NF-AODV	0.34	8.02	99.10	25joule
3.	61	SNF-AODV	0.45	5.12	99.60	17joule
4.	61	EENF-AODV	0.56	4.05	99.75	12joule

Throughput Performance

The EENF average throughput was high compared to the scheduling Neuro fuzzy routing. It used an Energy model so they increased the throughput level in the network. If the throughput is increased, the network performance also increased automatically.

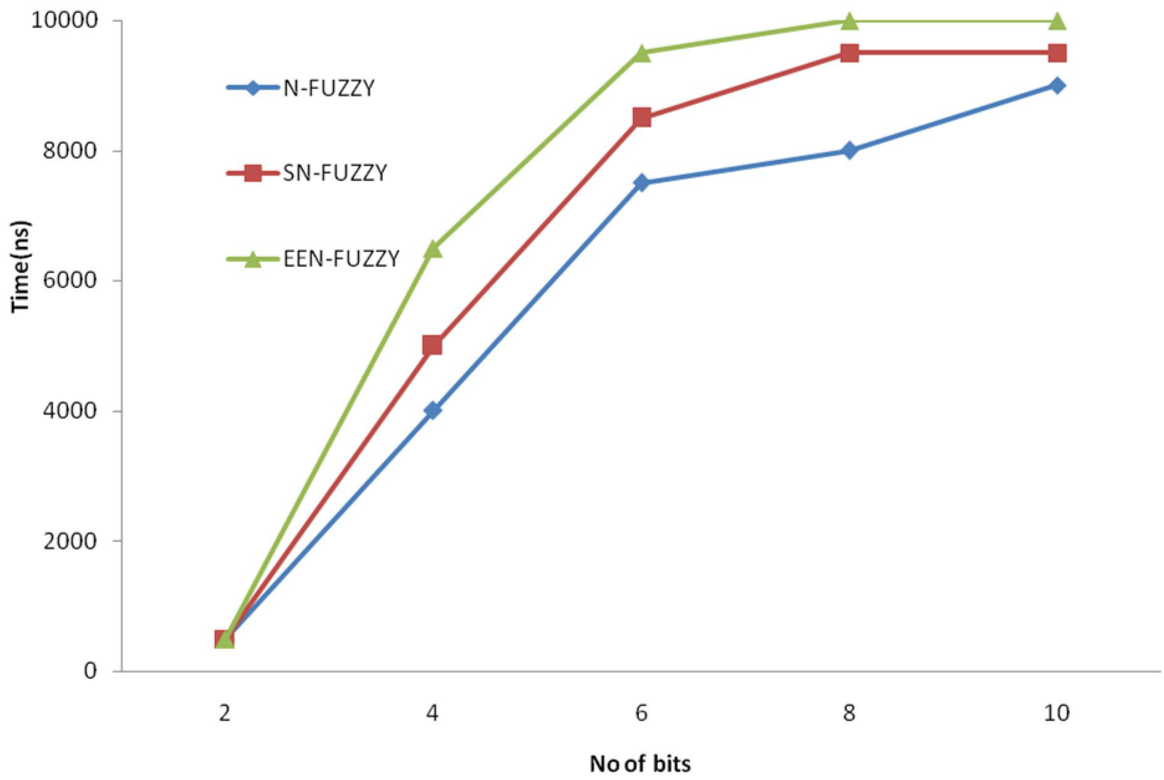

Figure 6.2: Throughput Performance of EENF-AODV

The performance of energy effficient neuro fuzzy logic is depicted in figure 6.2. Throughput is the ratio of successful packet delivery and minimum packet delay over a network.

Packet Delivery Fraction

The packet delivery is an amount of data received by the destination in the network. Packet delivery fraction is calculated by total packets received in the destination divided by total packets sent by the source in the network.

PDF = (Pr/Ps)*100

Where, Pr is total Packet received & Ps is the total Packet sent.

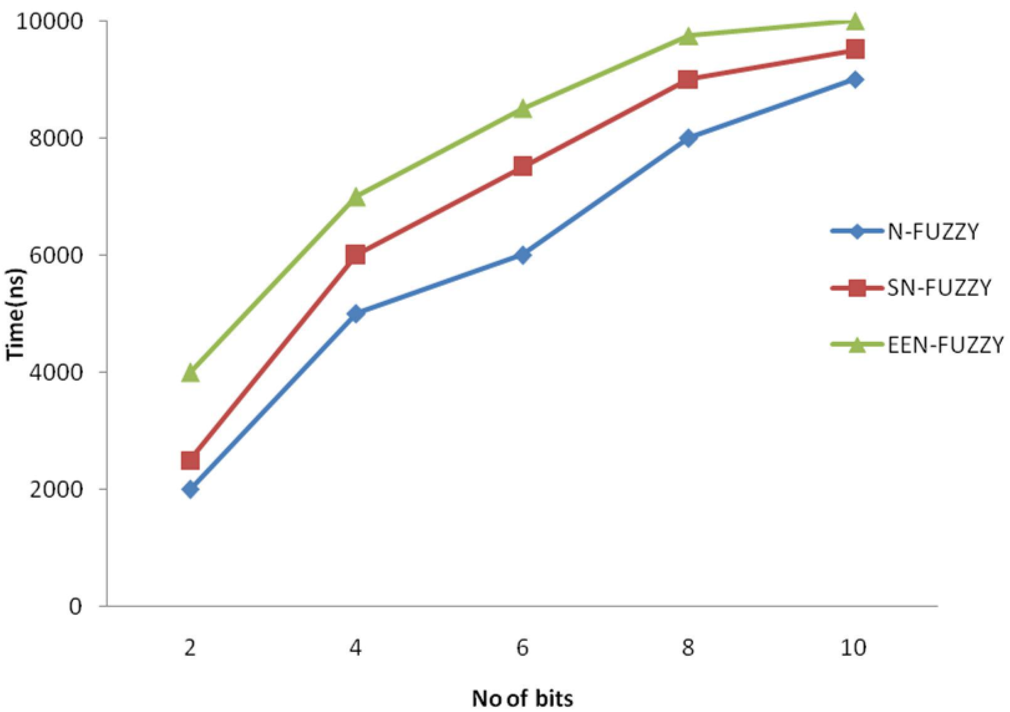

Figure 6.3: Packet Delivery Performance of EENF-AODV

Packet delivery calculates the data transmission between one node to another node in the network. The packet delivery performance for the EENF routing is depicted in figure 6.3. The EENF routing performance was better than the scheduling Neuro fuzzy logic routing. Fuzzy Logic has been used for routing and management of an ad-hoc wireless network.

End-to-End Delay

The End-to-End Delay is calculated from packet delay in the network. The data transmit from one node to another node. If there is any traffic or jamming intermediately in the network, it takes some time for data transmission. It is called End-to-End Delay in the network.

$$D = (Tr - Ts)$$

Where, Tr is receive Time and Ts is sent Time.

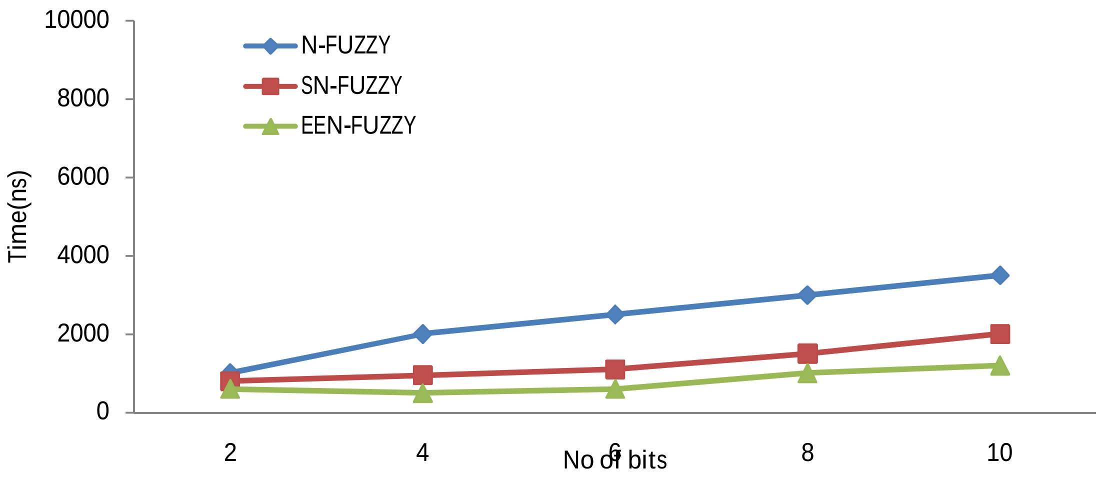

Figure 6.4: Delay Performance of EENF-AODV

The performance of delay for the EENF routing protocol with the connected dominating set routing algorithm is depicted in figure 6.4.

6.4 Energy Level of WMN

The energy level is a must and most important one of the quick data transmission in the network. It is calculated from each node energy consumption in the network.

Energy consumption = no. of packets * initial energy level

Remained energy = energy consumption – no. of packets in node

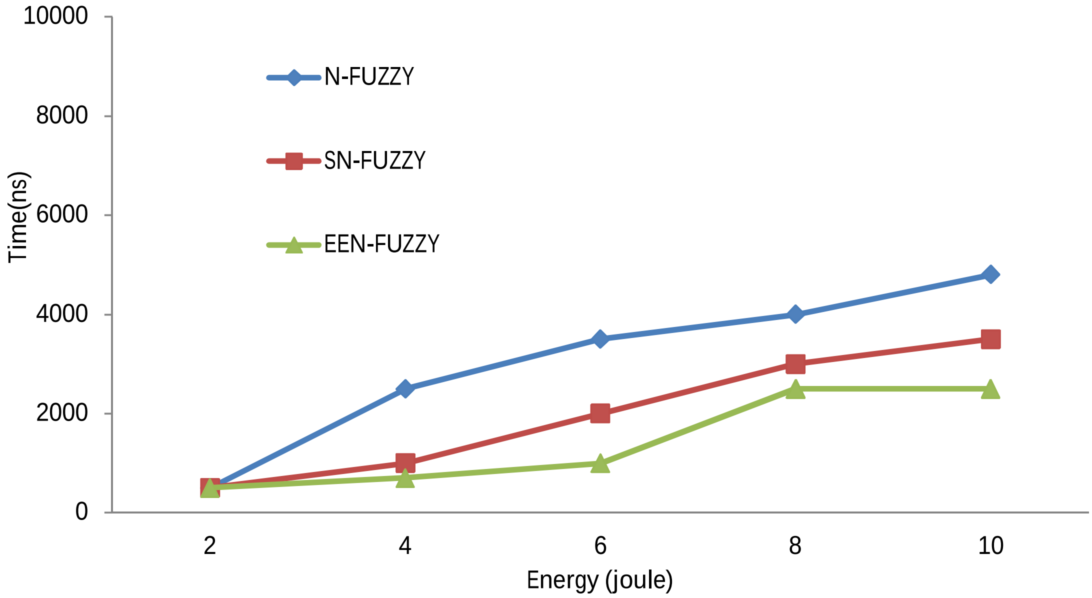

Figure 6.5: Energy Consumption of EENF-AODV

If any node in the network does not participate in data transmission, it saves the energy in the network. The energy level of EENF routing is depicted in figure 6.5.

6.5 Conclusion

Wireless mesh network using the Energy efficient Neuro fuzzy logic improved the data transmission and saved the energy model in the network. The Energy Efficient Neuro Fuzzy based dynamic CDS and MPR method on the wireless mesh network was presented. The CDS dynamically changed the place from one to another in the network. Multi Point relay was used to intermediate data transmission in the network. It was the most important and secured data processing in the network. In this network, the energy is the most important model of the system. They have to perform an MPR if there is no data process on the node to save the energy and reduce the energy consumption level. This network had to take parameters such as success ratio, average end-to-end delay, throughput and consumption of energy model in this network. All the parameters were taken to compare different network and energy levels.

CHAPTER 7

PERFORMANCE ANALYSIS OF MULTIPATH ENERGY EFFICIENT ALGORITHM

7.1 Introduction

The reactive routing protocols perform better in terms of packet delivery ratio and incur lower routing overhead especially in the presence of high mobility. In WMN, transfer of data takes place to and from the AP. Each node sends route requests to its neighbours. When the requests reach the different APs, they send back a route reply (Nogueira M 2012). The sending node receives all these replies and decides the route and AP based on different conditions. Since transfer of data in ad-hoc networks is similar to this, the existing ad-hoc routing protocols like DSR and AODV are used. But these protocols assume some properties of ad-hoc networks that are no longer true for WMN.

WMN presents an attractive alternative to this problem. Wireless Mesh Network consists of mobile hosts that generate traffic and backend routers that route traffic to desired destination. This wireless infrastructure is self-organizing, self-optimizing and fault-tolerant. This has made it to connect to regions that would have been otherwise unreachable by any single access technology. A Wireless Mesh Network is composed of communicating radio nodes organized in a mesh topology. It can be presented as a 3-layered network organization with mesh clients at the bottom most layers, mesh routers providing backend connectivity with distance locations and gateways for connecting with internet.

Wireless Mesh Networks (WMN) are undergoing rapid progress and inspiring numerous deployments. As a result, WMNs are expected to deliver wireless services in a large variety of scenarios of different scale, including personal, local, campus, and metropolitan areas. As in any other network, when WMN are in practice some routes are likely to become more heavily used than others. In contrary to wired networks, in wireless networks, due to the limited spectrum, it is hard or even impossible to over dimension the links. Therefore, techniques that allow taking full benefit of all available routes become of paramount importance in this setting. Multipath routing is a promising approach to achieve such goals. By establishing multiple paths between a source and a destination, one can balance the load among multiple routes and also increase the bandwidth available to the applications.

QoS metrics has been developed as a way of enabling traffic differentiation and allowing better quality services. Solutions based on QoS provide a set of control and assessment operations at the network (packet) level to ensure content dissemination with delivery guarantees. Traditional quality of service metrics, such as packet loss, delay, and jitter, are typically used to indicate the impact of network conditions on multimedia streams, but do not reflect the experience of end-users. Consequently, quality of service parameters fails regarding the evaluation of the content quality from the user’s perspective. To fulfill the gaps related to quality of service awareness routing approaches, new schemes have been proposed. QoS-based routing protocols aim to optimize the usage of network resources, the system performance and the quality level of multimedia applications. Therefore, with new WMN routing solutions, wireless operators can offer new services, reduce operational costs, while keeping and attracting new clients.

Quality of Service (QoS) for mobile users to access the Internet and multimedia service, there are single path and multipath routing protocols proposed and discussed. Single path routing protocols are easy to implement but it may suffer from frequent route discovering and cause significant latency and routing overheads when the mobility increases. Multipath routing aims to build multiple paths to increase fault tolerance and further to reduce routing overheads. When taking Internet connectivity into consideration, the traditional multipath routing protocols may encounter routing control messages flooding problem and gateway congested problem. The former is caused because that most of these protocols close the mechanism that intermediate nodes reply to the route request, so route request messages flood to the gateway and areas near the gateway become congested. This heuristic highlights QoS criteria in the MPR selection. Thus, MPRs are chosen based on QoS conditions, so the optimal links are published between a given pair of source and destination.

Efficient Implementation of Conditional Shortest Path Routing in Delay Tolerant Networks can provide good delivery performance and low end-to-end delay in a disconnected network graph where nodes may move freely. Some bridge nodes are identified based on their centrality characteristics, i.e., on their capability to broker information exchange among disconnected nodes. Due to the complexity of the centrality metrics in populated networks the concept of ego networks is exploited where nodes are not required to exchange information about the entire network topology, but only locally available information is considered.

The Routing exploits the exchange of pre-estimated between centrality metrics and locally determined social similarity to the destination node. There are proposed Conditional Shortest Path Routing (CSPR) algorithm and standard Shortest Path Routing (SPR). To collect several routing statistics, one has to generate traffic on the traces of these two data sets.

For simulation run, one must generate messages from a random source node to a random destination node at each second and assume that the nodes have enough buffer space to store every message they receive, the bandwidth is high and the contact durations of nodes are long enough to allow the exchange of all messages between nodes (Murray K and Pesch D 2004).

On demand routing protocols like AODV, DSR for ad-hoc networks use route discovery process to find the path between source and destination. In the source node initiates the route discovery when it has no route to the destination. It broadcasts a route request packet (RREQ) to its neighbours. Each receiving node in turn broadcasts RREQ packet (Mohammad S and Misagh B 2011). This process is repeated until the packet reaches the destination and the destination node will send the route reply message (RREP) to the source. This type of route discovery leads to broadcast storm problem.

To overcome this problem by implement the route discovery process in AODV using the dynamic CDS nodes only. When a CDS node receives a RREQ packet, it broadcasts the packet. The non-CDS are not rebroadcasting the RREQ packets. Thus the number of RREQ packet transmission is reduced and the network congestion is avoided.

Fuzzy logic is applied to select the best nodes for aggregation. The parameters such as trust level, power level and distance to the cluster head of each node are taken as input and fuzzy rules are formed. After applying the rules, the output will be treated as the best node or normal node or worst node. A minimum quantity size CDS does not guarantee the greatest favorable scheme presentation on or afterward an energy well-organized point of view.

The fuzzy will try to aggregate the packets of the best node and normal node, rejecting the worst node. Finally, the aggregated data from all the cluster heads will be sent to the sink. Since the fuzzy decision rule is based on trust and power level of the node, this approach is power efficient and secured. Moreover it does not involve any complex cryptographic operations, resulting in less overhead.

Multipath Routing has been used in literature to describe the class of routing mechanisms that allow multiple paths to be established between the source and the destination. Classical Multipath routing has been explored for two reasons. (i) Load Balancing: Traffic between the source and destination is split across multiple (partially or fully) paths. (ii) Use of multipath routing: increasing the probability of reliable data delivery. In these approaches multiple copies of the data are sent along different paths to avoid failure of a certain number of paths. Multiple path routing has been extensively studied and used in all kinds of existing communication networks like the Internet.

7.2 Secure Data Aggregation

Data Confidentiality

The transferred data which are very sensitive towards the passive attacks are safeguarded by maintaining the data confidentiality. Data confidentiality is the most basic issue related to security. In unreceptive environment such as wireless channel which are very susceptible to eavesdropping, data confidentiality is very important.

Cryptography techniques can maintain confidentiality but the complex encryption and decryption process are involved such as modular multiplications which includes more than a few public key based cryptosystems consuming power at high rate.

The idea is to split the original data packet into sub packets and then send each sub-packet through one of the available multipath. It has been found that even if some of these sub-packets were lost, the original message can still be reconstructed. According to their algorithm, it has also been found that for a given maximum node failure probability, using higher multipath degree than a certain optimal value will increase the total probability of failure.

Data Integrity

The extensive alteration of the ultimate aggregated value by the compromised source node or the aggregator node can be eliminated by maintaining data integrity. The shortage of high cost tampering-resistant hardware makes the sensor nodes get compromised in an effortless way. In case the sensor node possesses tampering-resistant hardware, it will be unreliable. Modification, forging and discarding of messages can be performed by the compromised node.

Use of Energy Efficiency

It is clear here that the cumulative traffic serviced by the node is also an important factor to be considered and it is not enough if only the number of overloaded nodes in the route is considered. Suppose a node on the route has a lot of collisions around it and if a high traffic is sent towards this node, then a lot of packets will be dropped due to buffer overflow during the backoff period. Moreover, packets may become invalid due to their long wait time in the queues. The problem in traffic balancing and shortest path routing like AODV is that it is not possible for efficient routing if only one constraint is considered as the various constraints are interrelated in the case of WMN.

Since wireless devices are generally battery-limited, energy consumption for the execution of estimation, learning, and decision making algorithms should be minimized. Therefore, lightweight protocols would be required to implement cognitive radio networks. Again, cognitive radio components in each node can co-operate to improve the efficiency of frequency usage due to the fact that some nodes might be unable to observe the environment accurately. With cooperative cognitive radio, the information obtained from observation and knowledge gained from a learning algorithm can be exchanged and shared among wireless nodes.

First-Hop Distance-Energy Efficiency

Analysis is made on the distance-energy efficiency for the first hop in a wireless ad-hoc network with randomly distributed nodes at the time of the first-hop transmission, even if a Multi-hop transmission is subsequently required for the packet to reach its ultimate destination.

Specifically, the first-hop distance-energy efficiency is defined as the ratio of the average progress of a packet during its first transmission and the energy consumption of that transmission. As any intermediate relay transmission can be viewed as a new first-hop transmission for the remaining route, the first-hop distance-energy efficiency should be consistent with the overall distance-energy efficiency of the entire route in a homogeneous environment.

Energy Consumption Model

A wireless network interface can be in one of the following four states:

- Transmit
- Receive
- Idle
- Sleep

Each state represents a different level of energy consumption.

• **Transmit**: Node transmits a frame with transmission power.

• **Receive**: Node receives a frame with reception power. That energy is consumed even if the frame is discarded by the node (because it was intended for another destination, or it was not correctly decoded).

• **Idle**: Even when no messages are being transmitted over the medium, the nodes stay idle and take note of the medium with Piddle.

• **Sleep**: When the radio is turned off and the node is not capable of detecting signals, no communication is possible. The node in sleep that is largely smaller than any other power.

Energy Efficient Model Steps

Step 1: Neighbour List

Step 2: Energy on network

Step 3: If neighbour_num =*1* then

Step 4: Return power (Distance, list [0].node)

End if

Step 5: For each *0≤ 1* < neighbour_num do

Step 6: If ratio < *0* continue;

//i+1 increment of power is smaller than length

Step 7: If ratio >*1* continues;

//i+1 increment of power is greater than length

Step 8: If 0<ratio > *1* break;

End for

Return power

The above algorithm is used to calculate the energy efficiency of network. It has neighbour node list based data transmission in the network. The data transmission is to take some energy on network and the power is calculated by joules per minute on system. The multipath path construction phase is made to create a set of neighbours that is the address of all nodes that are able to transmit data from the source.

During this process route request messages are exchanged between the nodes. Each node broadcasts the route request packet once and maintains its own routing table. When the node disseminates a data packet, it only needs to know its neighbouring node to transfer and doesn't need to maintain the whole path information, since the paths are formed whenever it is required unlike proactive routing protocols where it is necessary to store the routing information.

Balanced Routing

In this routing, nodes are designated as overloaded based on the medium use around them. If this medium usage exceeds a specific threshold value, then the node can be declared as overloaded. One method of choosing a route is to consider the number of overloaded nodes in a route. The routing protocol can decide the route based on the number of overloaded nodes in each of the available routes. The route with least number of overloaded nodes is chosen as the best route.

If two routes have the same number of overloaded nodes, then the one with the lesser number of hops is chosen. But this method is not a sufficient condition to check the load in a route. This is because overloaded nodes might differ in their extent of overloading.

Multi Transmission

It is used for number of purposes, including bandwidth aggregation, minimizing end-to-end delay, increasing fault-tolerance, enhancing reliability, load balancing, and so on. The idea of using multiple paths has existed for some time and it has been explored in different areas of networking. In the traditional circuit-switching network, alternate path routing was used to decrease the probability of call blocking.

In this scheme, the shortest path between two exchanges is used until it fails or reaches its capacity, when calls are routed through a longer, alternate path. In data network the idea of using multiple paths for end-to-end transport is common. Based on the assumption of stationary input traffic and unchanging network, the computation framework converges to minimize the overall delay in the network. The multipath routing method is shown in figure 7.1.

The source knows the destination and it is capable of, locally, finding the existing low-coupling routes to the destination. These routes are characterized by the set of the route transverses. Thus, source routing can be used to transmit individual packets via one of these paths (Mishra N K 2013) As a result, no additional route information is stored in intermediate nodes between the source and the destination.

In all experiments, multiple paths are used by letting the source send packets in a round-robin fashion among all the selected paths. Obviously, the protocol puts no constraints on the way of multiple paths used by the application.

Link capacity

WMN link capacity may change to the very nature of wireless which is sensitive to surrounding interference. Again this is critical when multiple technologies use same frequency band. Multipath Construction Phase and Data Transmission Phase are executed by using two messages namely route request message and route reply message.

Route Request message is transmitted when a node enters in the network to execute the neighbour discovery process during the network startup and also to establish a route to the destination. The Route Reply message is initiated from destination and reaches the source node to create a new entry in the local neighbour table.

Inter-path interference

Inter-path interference may occur between disjoint nodes. The point-to-multi point communication is opposed to point-to-point communication in case of wired technology. Hence neighbouring nodes may have impact on communication between two nodes leading to a well-known problem of hidden and exposed terminals.

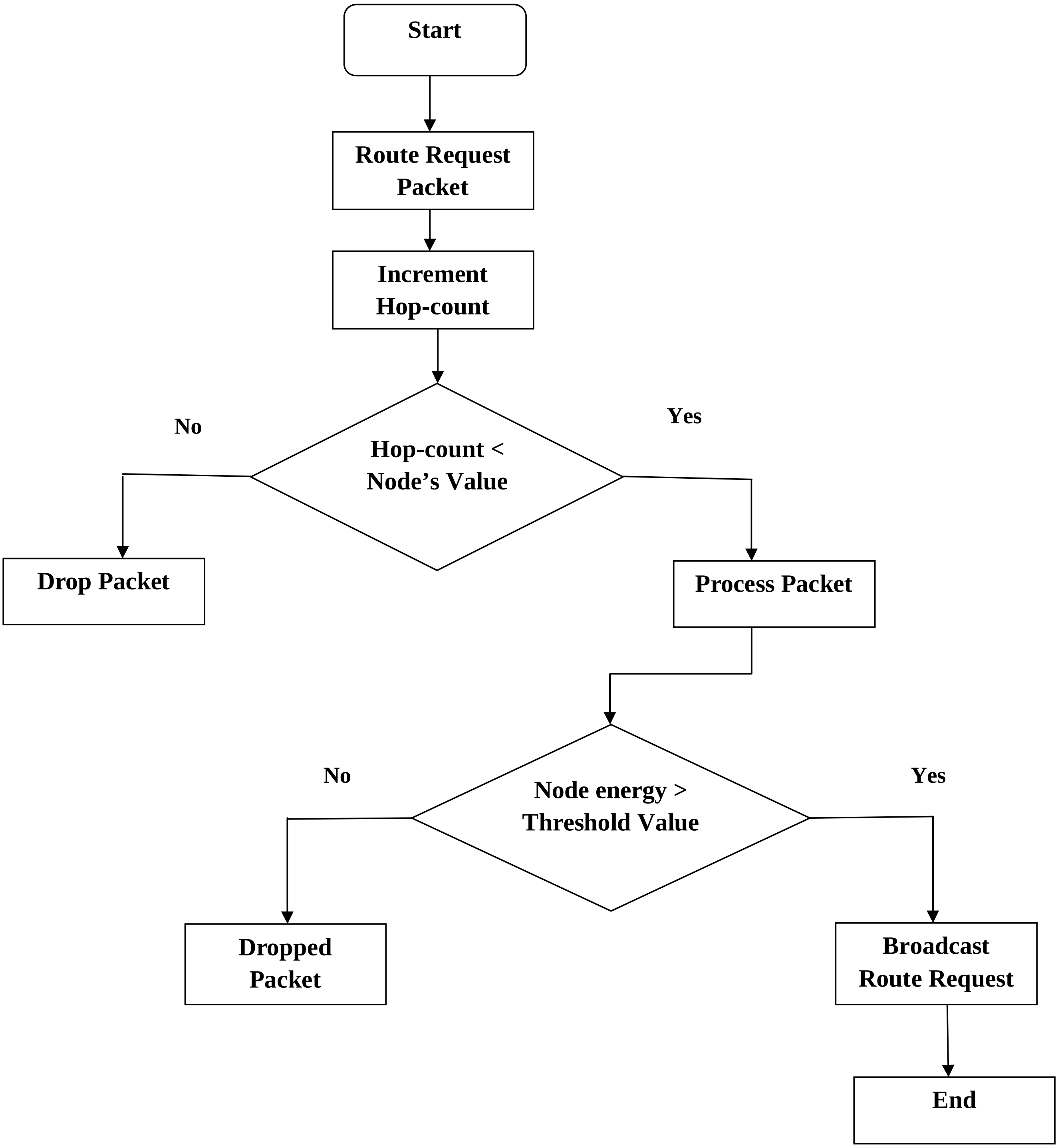

Figure 7.1: Multi Path Routing Method

Multipoint relay

Multipoint relay nodes publish links inside the messages which could constitute the paths from source to destination; then set of MPRs form a kind of backbone, in the mobile ad-hoc network. Thus, one promising issue of the routes selection optimization is to carefully select MPR that meets a given requirement to improve the targeted network performance.

7.3 Implementation of Multi Path Routing

Multipath Routing Method

A node k, $N1$ (k), $N2$ (k)

MPRk; MPR set of k

Begin

Step 1: Add to MPRk the node in $N1$ (k)

Which is the only one to reach a node in $N2$ (k)

Step 2: Remove the nodes from $N2$ (k) which are covered by a node in MPRk

Step 3: While ($N2$ (k) not empty) do

For each node in $N1$ (k),

(i) Calculate the number of nodes in $N2$ (k) that it can reach, that is, reach ability

(ii) Calculate Fi (k) to reach $N2$ (k)

Step 4: Add to MPRk the nodes which has the highest Fi (k),

If multiple choices, add which provide the highest reach ability, if multiple choices, select node with highest degree, that is, number of 1-hop neighbours

Step 5: Remove the nodes from $N2$ (k) which are covered by anode in MPRk

End

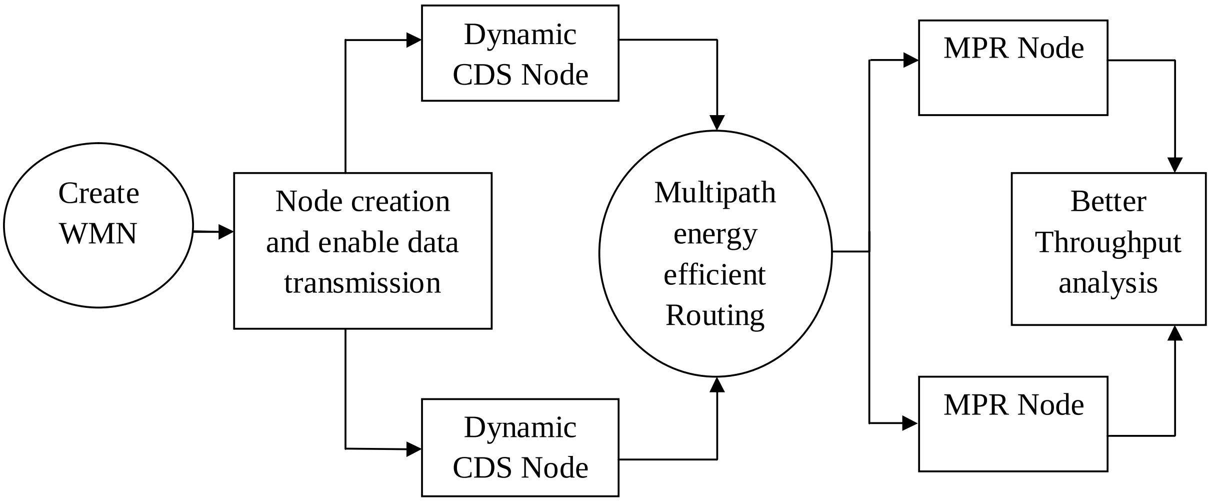

Figure 7.2: Multi Path Dynamic CDS Method

The figure 7.2 shows that the proposed architecture used a multipath routing to transmit data from source to destination in the network. Intermediate relay nodes are used to send a different path and multipoint route nodes on network. This system has better throughput performance on network.

7.4 Multi Path Energy Efficient Algorithm

S-Source, D-Destination, T-Traffic, P-Packets, M-message, DCD- Dynamic Connected Dominating R-Routing Information, MP-Multipoint Relay, U-uncovered Node, E-Energy

Step 1: Initialize network nodes

Initialize the Topology level

Send S message to D

Step 2: If (M=true)

S sends Packets to Dynamic route

Step 3: if Else (M=false)

Get T on Network Path

Step 4: Message send using MPR

S collects the R

Step 5: Routing Information Saved in the network

Shortest route on Path

Step6: Check if (MP=0)

Goto First Priority Node on Dynamic CDS Path

Dynamic CDS Change dynamically in the network

Step 7: if Else (F≠0)

Preprocess of Priority model

Choose different paths

Else

Waiting on network request

End

Step 8: Check Available Route otherwise

Step 9: Node's are sleep mode in the network

Step 10: Save Energy level on Network

Step 11: P send to S to D normally

Packets sending to Destination

Else

End

- The above algorithm uses an energy efficient data transmission on networks.
- If traffic occurred during the data sent from source to destination in the network, it will choose an alternate path and multi path routing.
- If multi path routing has a more relay node, it is used to collect the information from source to destination on the system.
- So it implements a secure and energy efficient based data transmission in the network.

7.5 Results and Discussions

The simulation result was obtained by using a network simulator to perform a good result in the network. The platform used was the NS-2. NS-2 is a discrete event simulator targeted at networking research. NS-2 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless networks.

The simulation environment is created in NS-2, a network simulator that provides support for simulating mesh wireless networks. NS-2 was written using C++ language and it uses the Object Oriented Tool Command Language (OTCL). It has been used to get a good throughput and report results in the network. It came as an extension of Tool Command Language (TCL).

Dynamic CDS based Energy Efficient Neuro Fuzzy Routing Decision was implemented using the Fuzzy Logic. The simulator with various input configuration settings and the statistics collected were analyzed in comparison with other well-known on demand routing protocol AODV. Our simulation modeled a network of nodes placed randomly within 1500 × 1500 meter area (Appendix). Each node had a radio propagation range of 250 meters and channel capacity. Two-way propagation model was used. The IEEE 802.11 distributed coordination function was used as the medium access control protocol. If all network topology to be set at the MAC based data representation on the progress.

The average size of the CDS increases with network density. The radio and IEEE 802.11 MAC layer models were used. The size of the data payload was 512 bytes. Data sessions with randomly selected sources and destinations were simulated. Each source transmits minimum rate of data packets to the destination in the network. Traffic classes were randomly assigned and simulation was carried out with different bandwidth requirements. There were no network partitions throughout the simulation. Each simulation was executed for 600 seconds of simulation time. The parameter values for simulation are shown in table 7.1.

Table 7.1: Parameters for MEE-AODV Simulation

Parameters	Value
Version	NS-all in one 2.28
Protocols	MEE-AODV
Propagation model	Free Space
Area	1500m x 1500m
Transmission Range	250 m
Traffic model	UDP,CBR
Packet size	1024 KB
Mobility Model	Random Way Point
Node's Mobility	0-100m/sec

Throughput Performance

The Number of throughput was observed with different conditions and comparison was made between the Multi path routing with existing routing protocol. It uses dynamic connected dominating set model, so it increased the throughput level in the network. If the throughput increased, the network performance was also increased automatically.

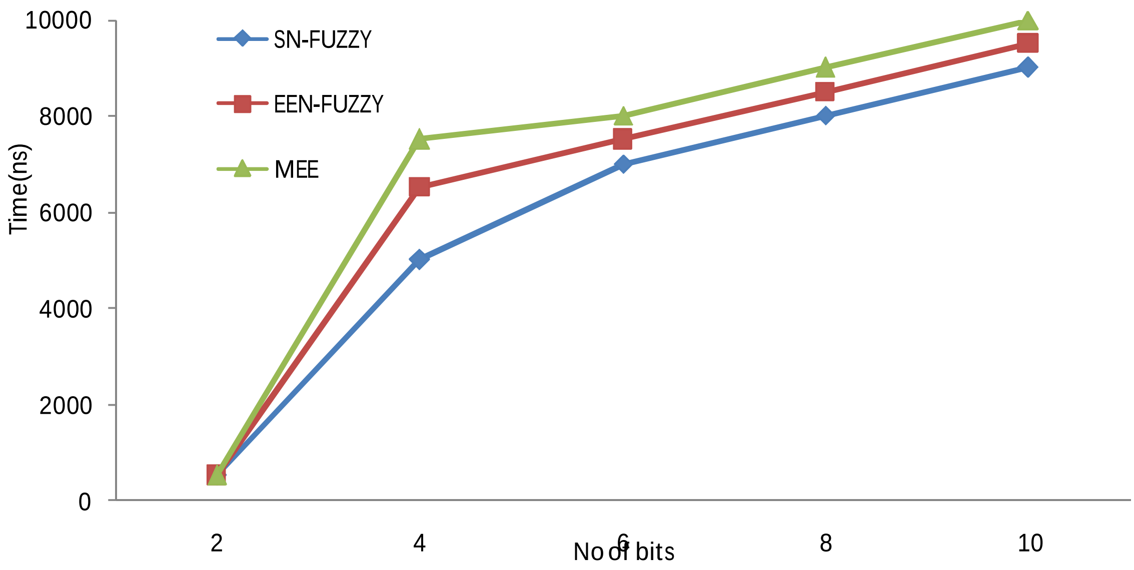

Figure 7.3 Throughput Performance of MEE-AODV

The MEE routing throughput level is high in the network. The throughput performance of MEE routing is depicted in figure 7.3.

Packet Delivery Fraction (PDF)

The packet delivery is the amount of data packets received by the destination in the network. It was calculated by total packets received in the destination divided by total packets originated by the source in the network. It is called as Packet Delivery Fraction. The performance of PDF in the network is shown in figure 7.4.

$$\textbf{PDF} = (\textbf{Pr}/\textbf{Ps})*\textbf{100}$$

Where, Pr is total Packet received & Ps is the total Packet sent.

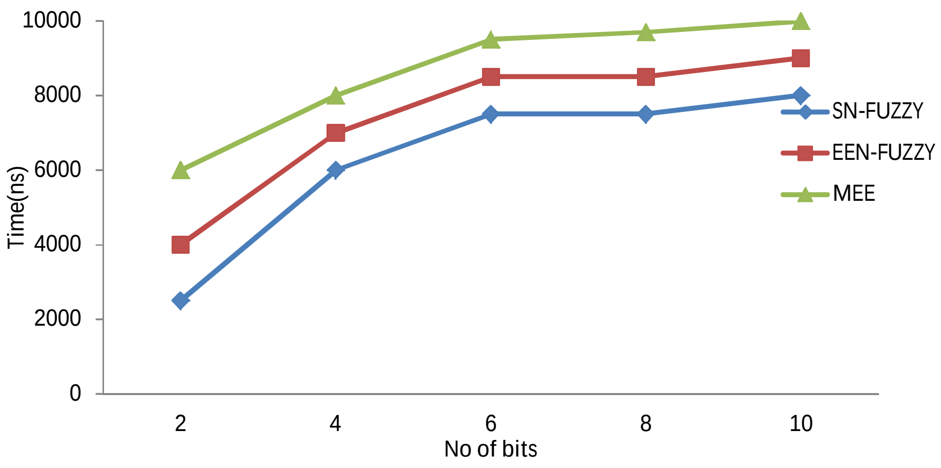

Figure 7.4 Packet Delivery Performance of MEE-AODV

End-to-End Delay

The packet delay in the network is called End-to-End Delay of the network. The data transmits from one node to another node. If there is any traffic or jamming intermediately in their network, it takes some time for data transmission. It is called packet delay in the network.

$$\mathbf{D = (Tr - Ts)}$$

Where, Tr is receive Time and Ts is sent Time.

The average end- to-end delay is the average time taken between packet sent from the source and successful packet received by the destination. Similarly each node includes the Hello message during creation of message. When a neighbour node receives this message, it calculates the difference between sent time and the current time. This is done in a synchronized network.

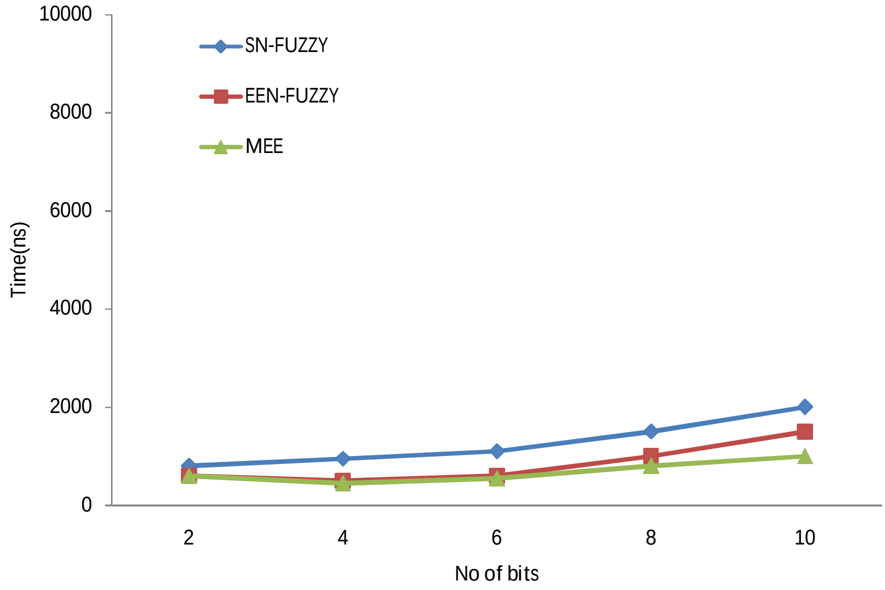

Figure 7.5 Delay Performance of MEE-AODV

The performance of delay for the MEE routing protocol reduced the delay in the network. The delay performance of MEE routing protocol and comparison of delay for different routing protocol is depicted in figure 7.5.

Energy Efficent model

The energy level of the network is a must and most important one of the quick data transmission in the network. It is calculated from each node energy consumption in the network. If any one of the node in the network does not participated in data transmission it saves the energy in the network.

Energy consumption = no. of packets * initial energy level

Remained energy = energy consumption – no. of packets in node

The route reply message carried the total residual energy of the route and the identity and the residual energy of the node with the least residual energy on that route. When the route replay arrived at the source, the forward route table was established and the source also stored the total residual energy of the route and the node with the least energy.

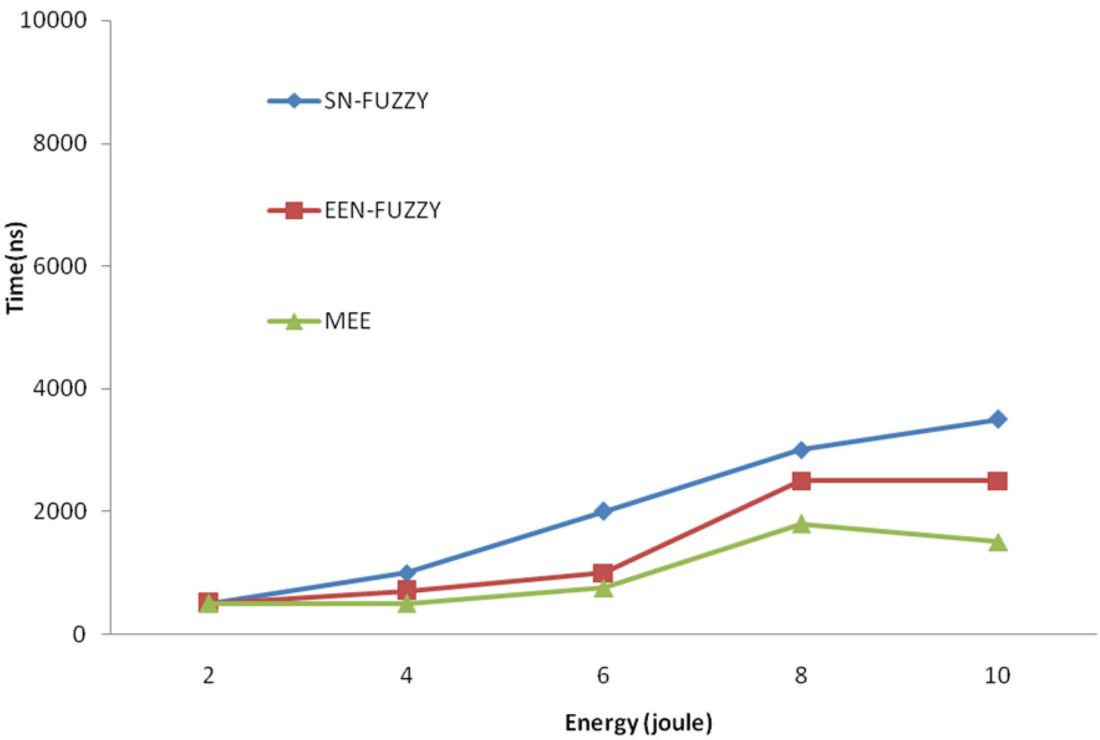

Figure 7.6: Energy consumption of MEE-AODV

From the average remained energy of nodes in the network after simulation has much higher residual energy than AODV. The multi path energy efficient routing energy consumption is depicted in figure 7.6. This result demonstrates that scheduling neuro fuzzy leads to lower total energy consumption in communication. The destination received the route request, it unicast the route reply message to the source using the backward route that had been constructed through the route request procedure.

7.6 Conclusion

The solution for the hypothesis has been approached in a strategic approach to have a numerical model and extensive simulation study. This work employed fast and effective routing algorithm which detected the routing failures. After the detection of failure, the energy efficient Neuro fuzzy logic algorithm was deployed. The multi path energy efficient algorithm was applied with the proposed method which increased the network performance, overcome the link failure, reduced the time delay, saved the energy and reduced the energy consumption level on network. An analysis for this algorithm proved its ability to support energy efficiency and scalability in the WMNs. Evaluation of this work is based on theoretical and performance analysis. The assumed parameters and the impact on the assumed parameters have also been carefully evaluated. The Overall efficiency of the suggested technique has been found to be very impressive and the solution for the formulated problem has been arrived successfully. Performance analysis on the existing techniques was also studied.

CHAPTER 8

CONCLUSION AND FUTURE SCOPE OF THE RESEARCH WORK

8.1 Conclusion

The solution for the hypothesis has been approached with a strategy to have an extensive simulation study. This work employed fast and effective multi path routing algorithm which detected the link failures and guarantees security based data transmission.

This approach choose optimal path to implement a data transfer using a shortest path routing model in CDS system. It considered the parameters such as throughput, delivery ratio, delay and energy model. Main focus is the energy efficiency and energy consumption in the network. Recovering from link-quality degradation, the quality of wireless links in WMN can degrade due to severe interference from other wireless networks. By switching the tuned channel of a link to other interference-free channels, local links can recover from such a link failure. They cope with heterogeneous channel availability: Links in some areas may not be able to access wireless channels during a certain time period due to range good manners or regulation.

Multipath energy efficient algorithm is deployed for network survivability. To reduce the energy consumption and link degradation, a multipath energy efficient routing algorithm is successfully developed and implemented.

The multipath energy efficient algorithm has been compared with the existing routing algorithms for various network parameters. The result obtained under simulated environment proves that this algorithm performance is better in terms of throughput, end-to-end delay, and delivery ratio and energy model when compared to routing algorithm under different load conditions.

Thus the reported research work focuses on the energy efficient, security based data transmission with a fast and effective multipath energy efficient routing. It also provides solution to the problems of link failure, link degradation and channel availability. On the whole, the efficiency of the suggested technique has been found to be very impressive and the solution for the formulated problem has been arrived successfully.

8.2 Future Work

Our hope efforts to execute a system density and safety based data communication in the network and to evaluate the energy model with different constraint in side-by-side association. Future work can be carried out to increase the throughput, delivery ratio and energy level in the network.

APPENDIX

Simulation parameters used in this study

PARAMETERS	VALUE
Version	NS-all in one 2.28
Propagation model	Free Space
Area	1500m x 1500m
Transmission Range	250 m
Traffic model	UDP,CBR
Packet size	1024 KB
Mobility Model	Random Way Point
Node’s Mobility	0-100m/sec

REFERENCES

1. Abedini, S.M. and Karimi, A. “Increasing The Lifetime Of Heterogeneous Sensor Network By Using Genetic-Fuzzy Clustering”, International Journal of Smart Sensors and Ad Hoc Networks, Vol.2, No.1, pp.56-60, 2012.

2. Aggarwal, N. and Gaur, D. “Fuzzy Based Routing Algorithm for Congestion Control in Internet”, International Conference on Computational Intelligence and Communication Networks (CICN), ISBN: 978-0-7695-5069-5, Vol.3, No.1, pp.291-295, 2013.

3. Anand, M. and Anand, U. “Impact of Relay Nodes on Vehicular Delay Tolerant Network”, International Journal of Computer Science and Communication, Vol.2, No.2, pp.653-656, 2011.

4. Bashar, A. and Parr, G. “Learning-Based Call Admission Control Framework for QoS Management in Heterogeneous Networks”, Springer Berlin Heidelberg, Vol.88, ISBN: 978-3-642-14305-2, pp.99-111, 2010.

5. Bourdoucen, H. and Azani, F. “Study of Fuzzy Logic-based Controller for Diff-Serv Bandwidth Broking”, Journal of Computing and Information Technology, Vol.21, No.1, pp.1–11, 2013.

6. Chandralekha. and Praffula, K.B. “Minimization of Number of Handoff Using Genetic Algorithm in Heterogeneous Wireless Network”, International Journal of Latest Trends in Computing, Vol.1, No. 2, pp.24-28, 2010.

7. Chelliah, M. and Sankaran, S. “Routing for Wireless Mesh Networks with Multiple Constraints Using Fuzzy Logic”, International Arab Journal of Information Technology, Vol.9, No.1, pp.1-8, 2012.

8. Chouhan, S. and Gaikwad, R.B. “Decision Strategies during vertical handover in heterogeneous networks”, International Journal of Advanced Research in Computer Engineering and Technology, Vol.2, No.6, pp.2021-2029, 2013.

9. Dana, A. and Ghalavand, G. “A Reliable routing algorithm for Mobile Adhoc Networks based on fuzzy logic”, International Journal of Computer Science Issues, Vol.8, No.3, pp.128-133, 2011.

10. De Miranda Rios, V. and de Castro Monteiro, C. “Alternatives to Network Selection in Heterogeneous Wireless Environments”, International Conference on Advanced Communication Technology (ICACT), pp.240-252, 2014.

11. Dely, P. “Cross-Layer Optimization of Voice over IP in Wireless Mesh Networks”, thesis, pp-1-45, 2010.

12. Dely, P., Kassler, A. and Bayer, N. “FUZPAG: A Fuzzy Controlled Packet Aggregation Scheme for Wireless Mesh Networks”, International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), Vol.2, pp.778-782, 2010.

13. Dora, L. “Secure data forwarding in wireless multi-hop networks for mobile users”, Theses, pp.1-30, 2010.

14. Elisangela, S.A. and Billy, A.P. “Trends and Challenges for Quality of Service and Quality of Experience for Wireless Mesh Networks”, http://www.intechopen.com, ISBN: 978-953-307-519-8, pp.127-148, 2014.

15. Giri, P.K. “A Survey on Soft Computing Techniques for Multi-Constrained QoS Routing in MANET”, IJCIT, Vol.3, No.2, pp.16-25, 2012.

16. Gupta, I. and Riordan, D. “Cluster-head election using fuzzy logic for wireless sensor networks”, Communication Networks and Services Research Conference, ISBN: 0-7695-2333-1, pp.255-260, 2005.

17. Harkous, H. and Makhlouta, J. “ACCOP: Adaptive Cost-Constrained and delay-optimized data allocation over parallel opportunistic networks”, International Conference on Mobile and Wireless Networking (iCOST), ISBN: 978-1-4577-2003-1, pp.70-75, 2011.

18. Kaloxylos, A. "Network Selection Algorithm for Heterogeneous Wireless Networks: from Design to Implementation", www.macrothink.org/npa, Vol.1, No. 2, pp.27-47, 2009.

19. Kalpana, G. and Punithavalli, M. "Fuzzy logic technique for gossip based reliable broadcasting in mobile ad hoc networks", Journal of Theoretical and Applied Information Technology, Vol. 51, No.3, pp.498-505, 2013.

20. karimi, A. and Abedini, S.M. "Cluster Head Selection Using Fuzzy Logic and Chaotic Based Genetic Algorithm in Wireless Sensor Network", Journal of Basic and Applied Scientific Research, Vol.3, No.4, pp.694-703, 2013.

21. Kassar, M. and Kervella, B. "An overview of vertical handover decision strategies in heterogeneous wireless networks", International journal of engineering, Vol.31, No.10, pp.2607-2620, 2008.

22. Kaur, K. and Goyal, S. "Optimized Routing in Wireless Ad-hoc Networks", IJECT, Vol.2, No.1, pp.69-74, 2011.

23. Khaled, S. and Khalil, I. "Communications in Smart Grid: A Review with Performance, Reliability and Security Consideration", Journal of Networks, Vol.8, No.6, pp.1229-1240, 2013.

24. Khare, A. and Sharma, A. "An Enhancement scenario of routing protocol scheme using TAODV protocol and fuzzy logic", IJATER, Vol.1, No.1, pp.1-5, 2011.

25. Kim, T.K. and Seo, H.S. "A Trust Model using Fuzzy Logic in Wireless Sensor Network", International Conference on Communication, Vol.44, pp.63-66, 2008.

26. Kumar, D. and Aseri, T.C. "Distributed Cluster Head Election (DCHE) Scheme for Improving Lifetime of Heterogeneous Sensor Networks", Tamkang Journal of Science and Engineering, Vol.13, No.3, pp.337-348, 2010.

27. Kunarak, S. and Suleesathira, R. “Predictive RSS with Fuzzy Logic based Vertical Handoff Decision Scheme for Seamless Ubiquitous Access”, www.intechopen.com, pp.262-280, 2008.

28. Lertsuwanakul, L. and Coltzau, H. “Multiple Criteria Routing Approaches in Mesh Overlay Networks”, International Journal on Advances in Networks and Services, Vol.3, No.3, pp.391-401, 2010.

29. Lertsuwanakul, L. and Unger, H. “Fuzzy-Based Multi Criteria Routing Algorithm in Mesh Overlay Networks”, Journal of Communication and Computer, Vol.8, No.1, pp.645-654, 2011.

30. Li, X., Wu, J. and Lin, S. “Channel switching control policy for wireless mesh networks”, Journal of Parallel and Distributed Computing, Vol.72, No.10, pp.1295-1305, 2012.

31. Luo, H. “Routing Connections with Differentiated Reliability Requirements in WDN Mess Network”, IEEE Transactions on Networking, Vol.17, No.1, pp.253-266, 2009.

32. Ma, L. and Denko, M.K. “A Routing Metric for Load-Balancing in Wireless Mesh Networks”, International Conference on Advanced Information Networking and Applications Workshops, Vol.2, pp.409-414, 2007.

33. Maji, A. “Load Balancing in Wireless Mobile Ad-hoc Networks”, e-Thesis, pp-2-34, 2010.

34. Makhlouta, J. and Harkous, H. “Adaptive Fuzzy Spray and Wait: Efficient Routing for Opportunistic Networks”, IEEE Conference on Mobile and Wireless Networking, Vol.1, No.1, pp.64-69, 2011.

35. Mamoun, M.H. and Barrak, S. “Adaptive Priority Routing Protocol for DTN Networks”, International Journal of Engineering and Technology, Vol.3, No.3, pp.258-264, 2013.

36. Matos, R. and Sargento, S. "Context-based Wireless Mesh Networks: A Case for Network Virtualization", Journal of Telecommunication Systems, Vol.51, No.4, pp.259-272, 2012.

37. Milanes, V. and Alonso, J. "Cooperative Maneuvering in Close Environments among Cybercars and Dual-Mode Cars", IEEE Trasaction on Intelligent Transportation Systems, Vol.12, No.1, pp.15-24, 2011.

38. Mirabedini, S.J. and Teshnehlab, M. "AFAR: Adaptive Fuzzy Ant-Based Routing For Communication Networks", Journal of Zhejiang University Science, Vol.9, No.12, pp-1666-1675, 2008.

39. Mirabedini, S.J. and Teshnehlab, M. "Flar: An Adaptive Fuzzy Routing Algorithm for Communications Networks Using Mobile Ants", International Conference on Convergence Information Technology, Vol.39, No.7, pp.686-704, 2008.

40. Mishra, N.K, "Sensor Energy Optimization Using Fuzzy Logic in Wireless Sensor Networking", International Journal of Research Review in Engineering Science and Technology, Vol.2, No.1, pp.11-14, 2013.

41. Mohammad, S. and Misagh, B. "A New Paradigm for Load Balancing in WMNs", International Journal of Computer Networks (IJCN), Vol.3, No.4, pp.1-12, 2011.

42. Murray, K. and Pesch, D. "Intelligent Network Access and Inter System Handover Control in Heterogeneous Wireless Networks for Smart Space Environments", IEEE Conference on Wireless Communication System, ISBN: 0-7803-8472-5, pp.66-70, 2004.

43. Narasimhan, B. and Padmapriya, R.S. "Fuzzy Logic Based Energy Aware Lustering Protocol (Fl-EACP) For Heterogeneous Mobile Ad-hoc Networks", International Journal of Advanced Research in Computer Science and Software Engineering, Vol.3, No.4, pp-37-41, 2013.

44. Nieto, A. and Lopez, J. "Traffic Classifier for heterogeneous and cooperative routing through Wireless Sensor Networks", International Conference on Advanced Information Networking and Applications Workshops (WAINA), Vol.1, No.1, pp.607-612, 2012.

45. Niyato, D. Hossain, E. "Cognitive radio for next-generation wireless networks: an approach to opportunistic channel selection in IEEE 802.11-based wireless mesh", IEEE Transaction on Wireless Communications, Vol.16, No.1, pp.46-54, 2009.

46. Nogueira, M. "A Security Management Architecture for Supporting Routing Services on WANETs", IEEE Transactions on Network and Service Management, Vol.9, No.2, pp.156-168, 2012.

47. Obula Reddy, B.G. and Ussenaiah, M. "An Adaptive Secure Fuzzy Multicast communication in Large Scale Mobile Ad-hoc Networks", International Journal of Computer Science and Network Security, Vol.13, No.11, pp.70-79, 2013.

48. Obulla Reddy, B.G. and Ussenaiah, M. "An Adaptive Fuzzy Clustering and Location Management in Mobile Ad-hoc Networks", International Journal of Computer Applications & Information Technology, Vol.1, No.3, pp.99-106, 2012.

49. Oliveira, T. and Mahadevan, S. "Handling Network Uncertainty in Heterogeneous Wireless Networks", IEEE INFOCOM, pp.2390-2398, 2011.

50. Omari, M. "Global and Local Sensor Clustering Using Genetic Algorithms and Fuzzy Logic", CTIC, Vol.2, No.1, pp.33-36, 2012.

51. Ormond, O. and Muntean. "Dynamic Network Selection in Wireless LAN/MAN Heterogeneous Networks", IEEE International Symposium on World of Wireless, Mobile and Multimedia Networks (WoWMoM), Vol.1, No.1, pp-1-59, 2011.

52. Ortiz, A.M. and Olivares, T. "Smart Routing Mechanism for Green ZigBee-based Wireless Sensor Networks", IEEE Symposium on Computers and Communications (ISCC) , Vol.3, No.1, pp.397-403, 2011.

53. Ortiz, A.M. and Royo, F. "Intelligent Route Discovery for ZigBee Mesh Networks", IEEE International Symposium on World of Wireless, Mobile and Multimedia Networks (WoWMoM), Vol.2, No.4, pp.1-6, 2011.

54. Ortiz, A.M. and Olivares, T. "Fuzzy Logic Applied to Decision Making in Wireless Sensor Networks", www.intechopen.com, ISBN: 978-953-51-0337-0, pp.221-240, 2012.

55. Parimal, K.G. "A Survey on Soft Computing Techniques for Multi-Constrained QoS Routing in MANET", IJCIT, Vol.3, No.2, pp.16-25, 2012.

56. Popescu, A. and Ermana, D. "A Multi-Dimensional CAN Approach to CRN Routing", Sixth International Working Conference on Performance modeling and Evaluation of Heterogeneous Networks HET NETs, pp.259-272, 2010.

57. Pushpalakshmi, R. and Vincent, A. K. "A Secure Dominating set based routing and key management scheme in Mobile Ad-hoc Network", WSEAS Transactions on Communications, Vol.10, No.10, pp.297-307, 2011.

58. Radunovic, B. "Toward Practical Opportunistic Routing with Intra Session Network Coding for Mesh Networks", IEEE transactions on networking, Vol.18, No.2, pp.421-433, 2010.

59. Ramakrishnan, M. "Distributed Multipath Routing Protocol for Wireless Networks", International journal of communication networks, Vol.8, pp.108-113, 2012.

60. Razvan, R. and Deaconescu, D. "Optimization Strategies for MPLS Traffic Engineering", International journal of Engineering, Vol.71, pp.91-102, 2009.

61. Saiful, A. and Anwar, F. “Performance Comparison of Proactive and Reactive Multicast Routing Protocols over Wireless Mesh Networks”, International Journal of Computer Science and Network Security, Vol.9 No.6, pp.55-62, 2009.

62. Sakthidharan, G.R. and Chitra, S. “A Fuzzy Energy Management Approach for Multimedia Traffic in WSN”, Life Science Journal, Vol.10, No.4, pp.505-510, 2013.

63. Santhi, G. and Nachiappan. “An Agent-assisted Fuzzy cost based Multicast QoS routing in MANETs”, WSEAS Transactions on Communications, Vol.12, No.3, pp.96-106, 2013.

64. Santhosh Baboo, S. and Narasimhan, B. “A Hop-by-Hop Congestion-Aware Routing Protocol for Heterogeneous Mobile Ad-hoc Networks”, International Journal of Computer Science and Information Security, Vol.3, No.1, pp.1-7, 2009.

65. Saraswala, P.P. “A Survey on Routing Protocols in ZigBee Network”, International Journal of Engineering Science and Innovative Technology, Vol.2, No.1, pp.471-476, 2013.

66. Senthil, K.R. “Implementation of AODV protocol with and without fuzzy logic for reliable multicast routing in ad-hoc networks”, International Journal of Scientific & Engineering Research, Vol.3, No.4, pp.1-6, 2012.

67. Shafigh, A. and Kamran, A. “Improving Performance of on Demand Multicast Routing Protocol by Fuzzy Logic”, World Applied Sciences Journal, Vol.13, No.11, pp.2323-2337, 2011.

68. Shakti, K. and Brahmjit, S. “Soft Computing Framework for Routing in Wireless Mesh Networks: An Integrated Cost Function Approach”, International Journal of Electronics, Computer and Communication Technologies, Vol.3, No.3, pp.25-32, 2013.

69. Sharma, M. and Khola, R.K. “An Intelligent Approach for Handover Decision in Heterogeneous Wireless Environment”, International Journal of Engineering (IJE), Vol.5, No.5, pp.452-462, 2011.

70. Sharma, S. and Kumar, S. “Routing in Wireless Mesh Networks: Two Soft Computing Based Approaches”, International Conference on Wireless Networks, Vol.3, pp.29-39, 2013.

71. Shehu, A. and Maraj, A. “Fuzzy Logic Approach for QoS Routing Analysis”, www.intechopen.com, pp.152-172, 2012.

72. Shekhar, T.P. “Improving QoS in Adhoc Networks Using Fuzzy Network”, International Journal of Advanced Research in Computer Science and Software Engineering, Vol.2, No.10, pp.130-135, 2012.

73. Singh, T.P. and Das, V. “Multicast Routing Protocols in MANET”, International Journal of Advanced Research in Computer Science and Software Engineering, Vol.2, No.1, pp.1-6, 2012.

74. Singhrova, A. and Prakash, N. “A Review of Vertical Handoff Decision Algorithm in Heterogeneous Networks”, International Conference on Mobile Technology, Applications, and Systems, pp.68-71, 2007.

75. Sohan, G. and Payal, K. “A Fuzzy Logic Based Network Dependent Routing Algorithm for Ad-hoc Wireless Networks”, International Journal of Engineering Research and Applications, Vol.1, No.1, pp.1-10, 2011.

76. Suman, S. and Sukhdip, S. “Pairs: Algorithm for Secure Heterogeneous Wireless Networks”, Journal of Information Systems and Communication, Vol.3, No.1, pp.210-214, 2012.

77. Sun, B. and Gui, C. “Fuzzy Controller Based QoS Routing Algorithm with a Multiclass Scheme for MANET”, International Journal of Computers, Communications & Control, Vol.4, No.4, pp.427-438, 2009.

78. Tabash, K. and Mamun, M.A.A. “A Fuzzy Logic Based Network Congestion Control Using Active Queue Management Techniques”, Journal of Scientific Research, Vol.2, No.2, pp.273-284, 2010.

79. TalebiFard, P. and Leung, V. “Context-Aware Mobility Management in Heterogeneous Network Environments”, Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, vol,2, No.2, pp.19-32, 2008.

80. Tran, A.H. and Mellouk, A. “User to User adaptive routing based on QoE”, IEEE Symposium in Programming and Systems, pp.39-45, 2011.

81. Tripathi, M.R. and Gaur, K. “Energy Efficient Fuzzy Logic Based Intelligent Wireless Sensor Network”, Progress in Electromagnetics Research Symposium Proceedings, Vol.1, No.1, pp.91-95, 2010.

82. Waldir, M. “Using Fuzzy Link Cost and Dynamic Choice of Link Quality Metrics to Achieve QoS and QoE in Wireless Mesh Networks”, Journal of Network and Computer Applications, Vol.34, No.2, pp.505-516, 2011.

83. Wankhade, S.B. and Ali, M.S. “Recent Trends In Ant Based Routing Protocols For Manet”, International Journal of Advances in Engineering & Technology, Vol.4, No.1, pp.405-413, 2012.

84. Watkins, L. and Beyah, R. “Passive Identification of Under Utilized CPUs in High Performance Cluster Grid Networks”, IEEE Conference on Communications, pp.408-413, 2008.

85. Xi, N. and Shen, Y. “The QoS-Ensured Vertical Handoff Decision in Heterogeneous Wireless Networks”, Journal of Information Science and Engineering , Vol.2, No.1, pp.875-893, 2014.

86. Zafeiris, V.E. and Giakoumakis, E.A. “An Agent-based Architecture for Handover Initiation and Decision in 4G Networks”, International Symposium on "A World of Wireless, Mobile and Multimedia Networks", pp.72-77, 2005.

87. Zeng, Y. and Xiang, K. "Directional routing and scheduling for green vehicular delay tolerant networks", Journal of Wireless Network, Vol.19, No.2, pp.161-173, 2013.

88. Zeynali, M. and Khanli, L.M. "TBRP: Novel Tree Based Routing Protocol in Wireless Sensor Network", International Journal of Grid and Distributed Computing, Vol.2, No.4, pp.35-48, 2009.

PUBLICATIONS

1. Sasikala, K. and Rajamani, V. ”A Modified Fuzzy Logic Routing for Wireless Mesh Network”, International Journal Of Computer Applications, ISSN: 0975 – 8887, Volume 60, Issue 2, pp.1-7, 2012.

2. Sasikala, K. and Rajamani, V. ”A Neuro Fuzzy Based Conditional Shortest Path Routing for Wireless Mesh Network”, International Journal of Enhanced Research in Management & Computer Applications, ISSN: 2319-7471, Volume 2, Issue 5, pp.1-10, 2013.

3. Sasikala, K. and Rajamani, V. ”An Improved Neuro Fuzzy Scheduling Based Route Discovery and Connected Dominating Set in Wireless Mesh Network”, International Journal of Advance Research, ISSN: 2320-9194, Volume 1, Issue 8, pp.1-9, 2013.

4. Sasikala, K. and Rajamani, V. ” An Energy Efficient Dynamic Connected Dominating Set with Multi Point Relay for Wireless Mesh Network”, International Journal of Scientific and Engineering Research, ISSN: 2229-5518, Volume 5, Issue 11, pp.1-15, 2014.