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A Neuro Fuzzy based conditional shortest path routing protocol for wireless mesh network

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Abstract: A modified nuero fuzzy based conditional shortest path routing protocol for wireless mesh network is simulated and studied. In wireless mesh networks many routing protocols 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. These protocol congested the routes and overloaded AP's to reduce the congestion by avoiding a traffic aware process and to improving the network performance on the system. However, major problem based on routing, such as traffic, delay and low network performance. To make a efficient routing based on CSPR for wireless mesh network, a Neuro fuzzy logic routing is proposed in this paper. Neuro fuzzy logic to perform high level data to reach the destination, this one to choose the path from distance and time efficiency, network throughput, reduce delay on the network. Simulation results in ns-2 verify that they perform better than the existing fuzzy logic routing protocol.

Keywords: Wireless Mesh Network, Neuro Fuzzy Logic, Access Point, Fuzzy logic, Conditional Shortest Path, AODV.

1. INTRODUCTION

As various wireless networks evolve into the next generation to provide better services, a key technology, wireless mesh networks (WMNs), has emerged recently. In WMNs, nodes are comprised of mesh routers and mesh clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. WMN is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves (creating, in effect, an ad hoc network). This feature brings many advantages to WMNs such as low up-front cost, easy network maintenance, robustness, and reliable service coverage [1]. Mesh networking are managing a network, which is highly dynamic, in terms of topology, location of nodes and routing path.

WMN is a promising wireless technology for numerous applications e.g., broadband home networking, community and neighborhood networks, enterprise networking, building automation etc. It is gaining significant attention as a possible way for cash strapped Internet Service Providers (ISPs), carriers, and others to roll out robust and reliable wireless broadband service access in a way that needs minimal up-front investments. With the capability of self-organization and self configuration, WMNs can be deployed incrementally, one node at a time, as needed [2]. As more nodes are installed, the reliability and connectivity for the users increase accordingly. Deploying a WMN is not too difficult, because all the required components are already available in the form of ad hoc network routing protocols, IEEE 802.11 MAC protocol [3].

The architecture of WMNs can be classified into three main groups based on the functionality of the nodes as follows: The Infrastructure/backbone WMNs architecture is shown in Figure 1, where dash and solid lines indicate wireless and wired links, respectively. This type of WMNs includes mesh routers forming an infrastructure for clients that connect to them. The WMN infrastructure/ backbone can be built using various types of radio technologies, in addition to the mostly used IEEE 802.11 technologies. The mesh routers form a mesh of self-configuring, self-healing links among themselves. With gateway functionality, mesh routers can be connected to the Internet. This approach, also referred to as infrastructure meshing, provides backbone for conventional clients and enables integration of WMNs with existing wireless networks, through gateway/bridge functionalities in mesh routers. Conventional clients with Ethernet interface can be connected to mesh routers via Ethernet links. Infrastructure/Backbone WMNs are the most commonly used type.

Figure 1: Infrastructure/backbone WMNs

Client meshing provides peer-to-peer networks among client devices. In this type of architecture, client nodes constitute the actual network to perform routing and configuration functionalities as well as providing end user applications to customers. Hence, a mesh router is not required for these types of networks. The basic architecture is shown in Figure 2.

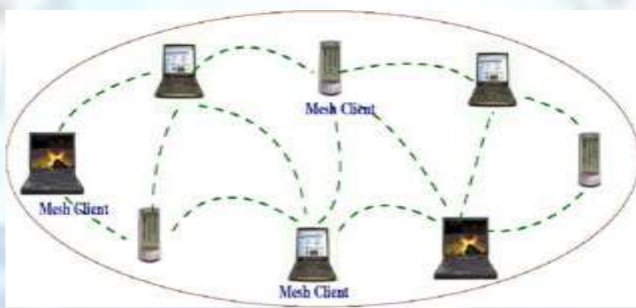

Figure 2: Client WMNs

The hybrid WMC architecture is the combination of infrastructure and client meshing as show in Figure 3. Mesh clients can access the network through mesh routers as well as directly meshing with other mesh clients. While the infrastructure provides connectivity to other networks such as the Internet, Wi-Fi, WiMAX, cellular, and sensor networks; the routing capabilities of clients provide improved connectivity and coverage inside the WMN.

Figure 3: Hybrid WMNs

Routing protocols are used to find and maintain routes between source and destination nodes, in order to forward traffic. To perform well in Wireless Mesh Networks, a routing protocol must be tailored to deal with the characteristics enumerated before. Routing protocols can be classified into proactive and reactive. Proactive protocols need to maintain routes between all node pairs all the time, while reactive routing protocols only build and maintain routes on demand [4]. Studies have shown that reactive routing protocols perform better in terms of packet delivery ratio and incur lower routing overhead especially in the presence of high mobility [5].

In WMN, transfer of data takes place to and from the AP. Each node sends route requests to its neighbors. When the requests reach the different APs, 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 [6] were used. But these protocols assume some properties of adhoc networks that are no longer true for WMN. In the case of ad-hoc networks, most of the transfer might be among the different computers in the 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 a few APs. Moreover, most of these ad-hoc protocols choose the shortest route to the destination. Some of the paths in the network are more utilized compared to others.

Hence, when these protocols are used in WMN it leads to congested routes. Some of the APs are over 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 in waiting at the queues. Also this leads to wastage of the bandwidth. Hence, there is a great demand for an efficient routing protocol for WMN [7]. Ad hoc On-Demand Distance Vector is a reactive protocol. Therefore it consists of two main phases: route discovery and route maintenance. Route discovery is the process to find a route between two nodes. It is initiated only when a node wants to communicate with another node and does not have the required routing information in its routing table. Route maintenance consists of repairing a broken route or finding a new one, and is initiated when a route failure occurs. During the route discovery, two paths have to be considered, the forward path and the reverse path. According to the way protocols record these paths, we can consider two different approaches:

a) Source routing:
The lists of hops traversed are 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.

b) Hop-by-hop routing:
The reverse path is stored in a table (routing table) in the nodes along the path. In hop-by-hop routing, the header overhead is replaced by the need to maintain routing tables in the intermediate nodes, with forwarding information [5].

AODV is based on hop-by-hop routing, i.e., it maintains routing table entries at intermediate nodes, which means it, uses hop-by-hop routing to forward traffic. Route discovery. The source node broadcasts a route request packet (RREQ) to its neighbors, which is uniquely identified by the pair (source address, broadcast id).When a node receives a RREQ, it can act the following way:

- If the RREQ was already received, it is dropped.
- If the RREQ has not been received and the node does not have a path to the destination, the RREQ is Re-broadcasted (with an increased hop count).
- If the RREQ has not been received and the node is the destination or has a route to the destination, a RREP (route reply) is sent to the source of RREQ.

Optimized Link State Routing (**OLSR)** is a proactive protocol designed for large and dense networks, where communication is assumed to occur frequently. OLSR uses two key concepts to compact the amount of control information sent in the messages and to reduce the number of retransmissions required to propagate them: multipoint relay and multipoint relay selectors.

Dynamic Source Routing (**DSR**) is, like AODV, a reactive protocol. However, as the name implies, it is a source routing protocol: the full path is included in the packet header, and this information is used to forward traffic. A lot of research is devoted to improve the ability of fuzzy systems [8], such as evolutionary strategy and neural networks. The combination of fuzzy logic and neural networks is called neuro-fuzzy system, which is supposed to result in a hybrid intelligent system by combining human-like reasoning style of neural networks.

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A neuro fuzzy logic routing is based on conditional shortest path routing [9]. It is efficient routing for traffic, delay and low network performance.

2. RELATED WORKS

A neuro fuzzy is hybrid system that incorporates the concept of fuzzy logic into the neural networks [10]. A fuzzy system consists of three blocks: fuzzification, fuzzy rules, and defuzzification/normalization. Each of the blocks could be designed differently. Fuzzification is supposed to convert the analog inputs into sets of fuzzy variables [11]. For each analog input, several fuzzy variables are generated with values between 0 and 1. The number of fuzzy variables depends on the number of member functions in fuzzification process. Fuzzy variables are processed by fuzzy logic rules [12], with MIN and MAX operators. The fuzzy logic can be interpreted as the extended Boolean logic. For binary "0" and "1" the MIN and MAX operators in the fuzzy logic perform the same calculations as the AND, OR operators in Boolean logic, respectively. As a result of "MAX of MIN" operations in fuzzy systems, a new set of fuzzy variables is generated, which later has to be converted to an analog output value by defuzzification blocks.

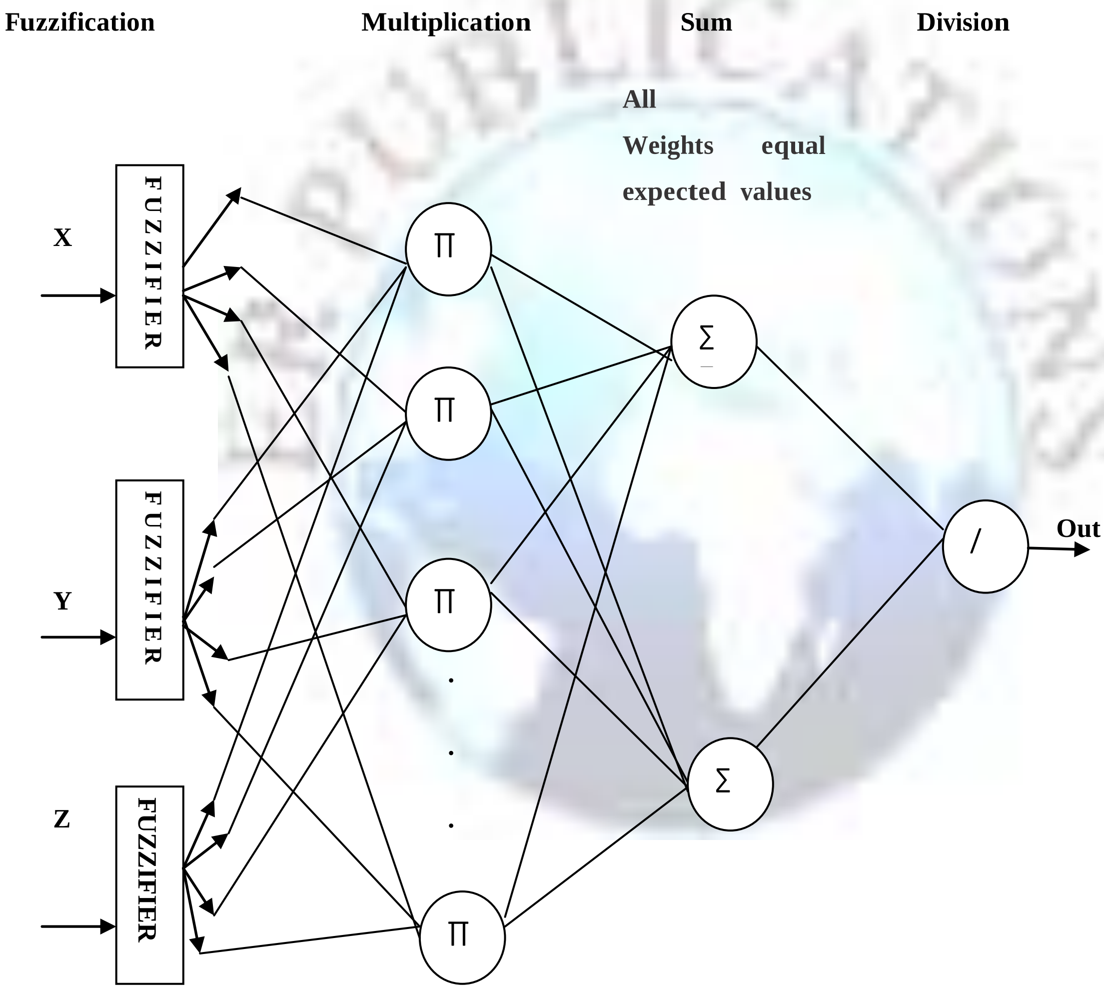

Figure 4: Neuro Fuzzy System

Figure 4 shows the neuro-fuzzy system which 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 [13]. Then, instead of MIN operations in classic fuzzy systems, product operations (signals are multiplied) are performed among fuzzy variables.

This neuro-fuzzy system with product encoding is more difficult to implement, but it can generate a slightly smoother control surface. 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 are all "1". Neuro-fuzzy system architecture resembles neural networks because cells there perform different functions than neurons, such as signal multiplication or division [14].

Conditional Shortest Path Routing (CSPR) protocol that routes the messages over conditional shortest paths in which the cost of links between nodes is defined by conditional intermeeting times rather than the conventional intermeeting times. CSPR achieves higher delivery rate and lower end-to-end delay [15]. Conditional shortest path routing (CSPR) protocol in which average conditional intermeeting times are used as link costs rather than standard intermeeting times and the messages are routed over the network . A comparison is made between CSPR protocol with the existing shortest path Routing (SPR) 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 [16]. It has shows how well the conditional intermeeting time represents internodes' link costs and helps making effective forwarding decisions while routing a message. 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.

Conditional Shortest path routing algorithm is a simple and easy to understand method. In basic design of this technique is to construct a graph of the subnet, with each node of the graph in place of a router and each arch of the graph representing a message line using link. For result a route between a given pair of routers, the algorithm just finds the shortest path between them on the graph. The length of a path can be measured in a number of ways as on the basis of the number of hops, or on the basis of area distance.

3. PROPOSED APPROACH

Neuro-fuzzy model will be developed for model identification, knowledge extraction and rule extraction purposes. The model is characterized by a set of rules which can be further used for representation of data in the form of data transfer from the source to destination on the variables. Therefore, in situation the fuzzy variables become such variables. The implementation of neuro fuzzy system in wireless mesh network (WMN) is achieved by using efficient neuro fuzzy logic algorithm [8] proposed in this paper .That make an efficient conditional shortest path routing for traffic avoidance, congestion control and high network performance.

The Neuro Fuzzy Logic based CSPR is the common ability to deal with traffic performance and then avoiding the congestion control more over on the network. Both of them instruct the information in a similar and distributed architecture in a mathematical framework. Hence it is possible to convert neuro-fuzzy logic architecture to a mesh network. It can make possible to combine the advantages of neuro-fuzzy logic. A network obtained this way could use excellent training algorithms that neural networks have at their removal to obtain the parameters that would not have been possible in fuzzy logic architecture [17]. The solution detects the Traffic occurred nodes and isolates it from the active data forwarding.

3.1 Neuro fuzzy routing

A source node S needs a route to some destination D, it broadcasts a route request message to its neighbors, including the last known sequence number for that destination. The route request is busy in a controlled manner through the network awaiting it reaches a node that has a route to the destination. Each node that forwards the route request creates a reverse route for itself back to node S. When the request route reaches a node with a route to D**,** that node generates a request reply that contains the number of hops necessary to reach D and the sequence number for D most recently seen by the node generating the reply. Each node that participates in forwarding this back toward the originator of the request route (node S) creates a forward route to D.

The performance ratio of neuro fuzzy routing is better than fuzzy routing it is plotted for each hour since the beginning of the trace collection. The ratio generally remains in the range, high on the other performance, with irregular conditions on the network. The result shows that our neuro fuzzy routing strategy performs competitively against the oracle routing strategy even without the knowledge of attack based demand on wireless network. In this performance level are so high and data loss level is low in condition, this is the main advantage of these work.

3.2 Neuro Fuzzy Logic Routing Algorithm:

```
   If S message D received then
      source A from neighbor 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 neighbor 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 NEURO FUZZY-SET logic
Enter total neighbor 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
```

3.3 Steps in Neuro Fuzzy Logic Method

Step 1: The data are sending by wireless mesh network from source (S) to destination (D), the Source node collects the neighbor node list.

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

Step 3: AP has to gather the data, sending and receiving process on 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 and if there any traffic occurred in Network path.

Step 6: The neuro fuzzy logic will select alternate route to send the data. It's mainly work on conditional shortest path routing in its function on the network.

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

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

Step 9: Neuro fuzzy operator is executing the packets.

Step 10: At that time defuzzification is also executed only if not equal to the packet loss.

4. RESULTS AND DISCUSSIONS

The goal of our simulation is to analyze the behavior of the **NF-AODV** by deploying mesh Networks [18]. 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). The simulations were carried out using a MESH environment consisting of 71 wireless mobile nodes roaming over a simulation area of 1500 meters x 1500 meters flat space operating for 10 seconds of simulation time. The radio and IEEE 802.11 MAC layer models were used. Nodes in our simulation move according to Random Waypoint mobility model, which is in 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 members leaves a group. Multicast sources start and stop sending packets; each packet has a constant size of 1024 KB. Each mobile node in the network starts its journey 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 proposed system consists of a well-organized tree construction scheme which 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, we also 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. Our imitation and experiential results in a real tested show that the proposed scheme is able to 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 20 m/s node speed and 3 identical source-destination connections.
The parameter values for simulation are shown in **Table 1.**

TABLE 1: Values for simulation

Parameters	Value
Version	Ns-allinone 2.28
Protocols	NF-AODV
Area	1500m x 1500m
Transmission Range	250 m
Traffic model	UDP,CBR
Packet size	1024 KB

4.1 NF-AODV metrics

NF-AODV has a number of quantitative metrics that can be used for evaluating the performance of mesh network. The following metrics for evaluating the performance is given in **Table 2.**

TABLE 2: Metrics for evaluating the performance

S. No	No. of Nodes	Protocol	Throughput	Average Delay	Pdf
1.	61	Aodv	0.28	18.28	95.2
2.	61	F-Aodv	0.29	11.01	98.0
3.	61	NF-Aodv	0.34	8.02	99.1

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4.2 Throughput Performance

Throughput performance is calculating by ratio of throughput and overall network performance. Improve the network performance by maximize packet delivery ratio and minimize packet delay.

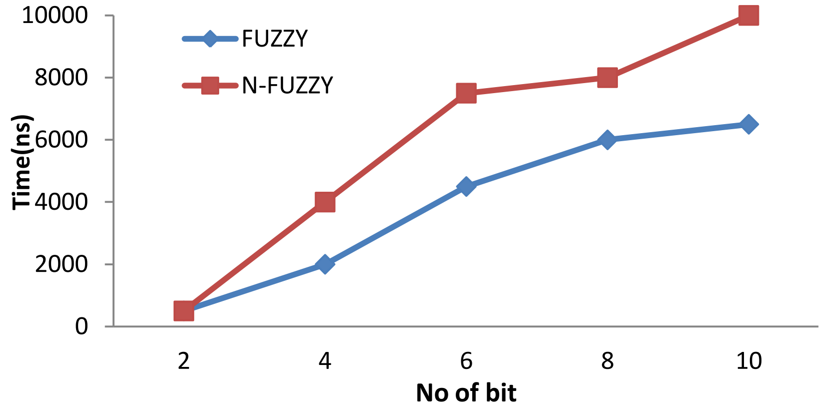

Figure 5: Performance of Neuro fuzzy logic

The performance of the throughput for fuzzy routing and the proposed Neuro fuzzy logic routing is depicted in **Figure 5**. The performance of Neuro fuzzy logic based routing throughput level is higher than fuzzy routing of the network. It is calculating the performance of throughput level and high accuracy of the data transferring on source to destination of the method. The higher in performance is due to the neuro-fuzzy logic engine is presented as an intelligent technique for discriminating packet loss due to congestion from packet loss by wireless induced errors. The results have shown that the fuzzy engine may distinguish congestion from channel error conditions on time. This graph is to distinguish between the fuzzy routing and then neuro fuzzy logic performance of the networks. In graph, the X and Y coordinates are to mention the number of bits and time to sending or receiving level respectively.

4.3 Packet Delivery Fraction

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

PDF = (Pr/Ps)*100

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

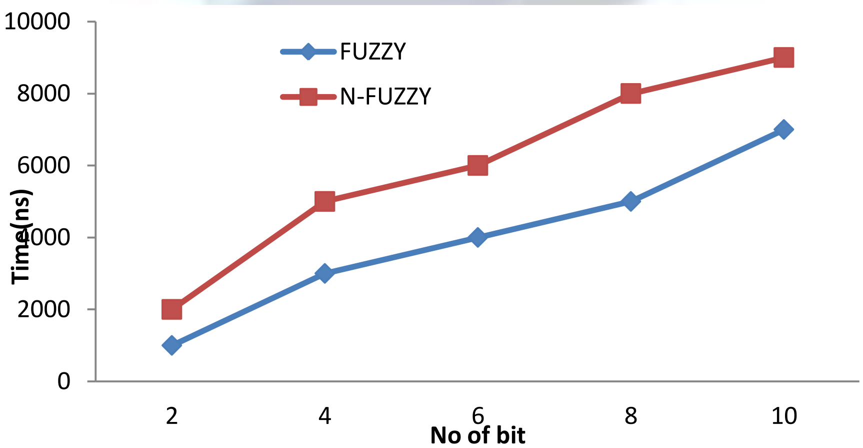

Figure 6 : DeliveryRatio of Neuro fuzzy logic

Delivery fraction is calculating the data transmission between the one node to another node of the network. The performance of the packet delivery fraction for the proposed routing and the fuzzy routing based on manual calculation. Fuzzy Logic has been used for routing and management of an ad hoc wireless network. The neuro fuzzy logic based routing algorithm takes into account input variables, delay, and throughput and energy consumption. It is differentiating performance between the existing and neuro fuzzy performance on the network. It is stating that at a time of process how many packets send and received during the process on the transmission and intermediately showing the difference in calculating the time take by packets to reach the destination.

The simulation output of the packet delivery ratio of the proposed Neuro fuzzy routing protocol and existing fuzzy routing protocol is shown in **Figure 6**. 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. To increases sub linearly with the number of delivered packets hence the per packet exploration cost are the numbers of delivered packets grow. It represents the number of control packets divided by the total number of received data packets. For this computation, every time a control packet is retransmitted, it is considered as a new control packet from the neuro fuzzy routing on the total area network performance of the process.

4.4 End-to-End Delay

Average end-to-end delay includes all possible delay caused by buffering during route discovery latency, queuing at the interface queue, retransmission delay at the MAC, propagation and transfer time. It is defined as the time taken for a data packet to be transmitted across an 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.

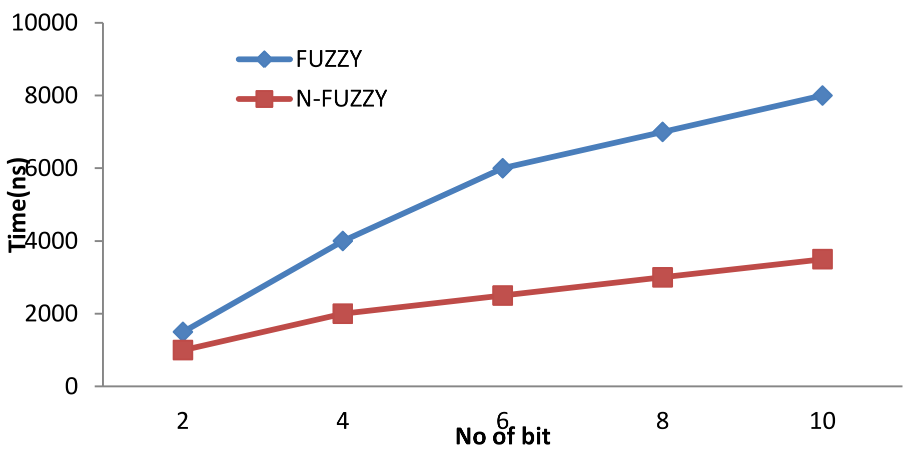

Figure 7: Delay comparision of existing with Neuro fuzzy logic

The performance of delay for the proposed routing protocol with the fuzzy routing is depicted in **Figure 7**. and also a comparison of delay for different nodes for the proposed routing protocol.Delay is used to calculate the packet droping level of the networks and then if data are dropped means the time taken by Neuro fuzzy logic routing is very low but Fuzzy logic routing is delaying to send and receive the data processing of 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 the data to route ,Neuro fuzzy logic is discovering the neighbour node to get active and send the data quickly when compred to fuzzy logic routing which delays its process.

5. CONCLUSION

Wireless mesh networks are becoming a promising option for last mile internet access as their initial infrastructure cost is 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 conditional shortest path routing is proposed in this paper. Our simulation results show 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.

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