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A Reliable And Trusted Routing Scheme In Wireless Mesh Network

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ABSTRACT: Wireless mesh networks (WMNs) are multi-radio, multi-hop networks with the ability of dynamically self configuring, self tuning, self-healing and self organizing. In WMN, transfer of data takes place to and from the access points (APs). Since wireless mesh networks are ad-hoc in nature, many routing protocols used for ad-hoc networks like AODV (Advanced on Demand Vector) are also used for WMNs by considering only the shortest route to destination. Data transfer through these protocols leads to congested routes and overloaded APs. Since, routing is a multi constraint problem. In order to reduce congestion and make routing decisions more reliable, routing decisions should be based on more than one constraint. For ensuring the route reliability, it is necessary to find out the route that lasts for longer time. This report is based on fuzzy logic, we have proposed a reliable routing scheme in order to obtain reliable route in WMNs. In this scheme for each node in wireless mesh network, we consider three parameters i.e. node residual energy, hop count and throughput. The proposed routing scheme maintains a reliable path from source to destination thus enhancing network life time and reduces number of packet loss during packet transmission. Simulation results indicate that proposed routing scheme has significant reliability enhancement as compared to other routing algorithms such as AODV. The simulation results show that the proposed routing scheme is effective and reliable.

Keywords-WMN, AODV, Fuzzy Logic, Membership Function, Fuzzy Inference

1. INTRODUCTION
Wireless mesh networks (WMN) are multi-radio, multi-hop networks with the ability of dynamically self organizing and self configuring. They can automatically establish ad hoc networks and maintain mesh connectivity between them. They are envisioned to be compatible and interoperable with existing wire line and wireless networks (conventional wireless, cellular networks, sensor networks) through gateways. WMN's diversify the abilities of ad hoc networks as they are composed of (a) Mesh routers and (b) Mesh clients

1.1 MESH ROUTERS
Mesh routers form the backbone infrastructure. Mesh routers are mainly stationary devices. Through multi-hop technology they can achieve the same coverage as a conventional router do but with much less power. They have additional routing functions that support mesh networking[1]. Its greatly helps the users by connecting them with wireless mesh routers through Ethernet even though they do not have wireless NICs, so user can be always online, anywhere and any time. Through gateway or bridge functions they integrate with different existing wireless networks such as cellular, wireless-fidelity (Wi-Fi) 802.11 a,b,g and 802.11n[2].

1.2 MESH CLIENTS
Mesh clients can be mobile or stationary as well. Mesh clients have necessary mesh functions and they can acts as a router but they do not have gateway or bridge functionality. They only have one wireless interface. We have large variety of devices that can acts as mesh clients [3].Mesh clients can also work as routers as they have necessary functions for mesh networking. Hardware and software for mesh clients is similar to mesh routers. However, mesh clients usually have a single wireless interface. Also, mesh clients have higher variety of devices compared to mesh routers. They can be laptop/desktop PCs, pocket PCs, PDAs, IP phones, RFID readers, BAC network (Building Automation and Control networks), controllers and many other devices [4].

2. ROUTING PROTOCOLS
Routing protocols can be classified into proactive and reactive. Proactive routing protocols need to maintain routes between all node pairs all the time, while reactive routing protocols [5, 6] only build and maintain routes on demand. Studies [7, 8] 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. 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. 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 (Dynamic Source Routing) [5] and AODV [6] were used. The Ad hoc On Demand Distance Vector (AODV) routing protocol is a very popular protocol in WMNs. It is reactive protocol in which route is established on demand by AODV. It does not use source routing. In this protocol each node maintains a routing table which contains destination address, next IP address and destination sequence number. Two major phases of AODV are route discovery and route maintenance. But these protocols assume some properties of adhoc networks that are no longer true for WMN [8]. 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

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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.

2.1 TRAFFIC BALANCING

In this routing, nodes are designated as overloaded based on the medium usage 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 [9]. 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. 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. Moreover lot of bookkeeping is done to keep track of the medium usage around a given node over a period of time. This leads to inefficient routing as route discovery phase takes a long time. To overcome the problems faced in traffic balancing, a fuzzy multi-constraint routing scheme is proposed in this paper.

3. FUZZY ROUTING

In a network like the WMN, 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 the different constraints. Multi-constrained routing is a NP complete problem and does not have a polynomial solution. It is required to use various heuristics and soft computing techniques to solve them [10]. A Fuzzy system is best suited in making optimal routing decisions in a network involving multiple constraints and multiple objectives. There are several studies of fuzzy multi-objective routing where a fuzzy system is implemented over classical methods like AODV to do multi-objective routing. A fuzzy routing algorithm based on several metrics for a mobile ad-hoc network is proposed in [11]. A fuzzy logic system where unnecessary routes are eliminated by removing links not accepted by the system is considered in [12]. An adaptive algorithm based on fuzzy logic to change the security level of the mobile node is proposed in [12]. In this paper, we consider a fuzzy system for making routing decisions in WMN where the destination AP is common for several users. Here it is necessary that the traffic gets spread across the system for maximum bandwidth usage. Various constraints that are considered are residual energy of nodes, the distance of source from the AP (hop count) and throughput/delay. The protocol has been simulated in MATLAB 7.0 in which Fuzzy Logic tool box has been used.

3.1 PROPOSED MULTI CONSTRAINT ROUTING USING FUZZY LOGIC

The block diagram of the proposed multi constraint routing using fuzzy logic is shown in Figure 1.

3.2 ROUTING WITH FUZZY LOGIC

In this routing, the constraints first undergo fuzzification and are mapped into sets using membership functions. Then the inference engine with the help of the rule base computes the fuzzy output. This fuzzy output is sent back after defuzzification.

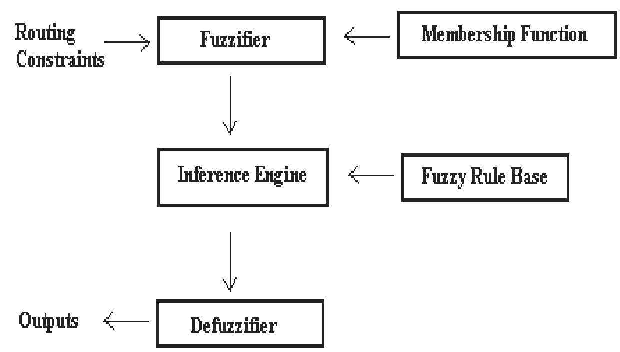

Figure 1: *Fuzzy Routing.*

The functions performed by various units in the fuzzy controller are explained as follows:

3.3 FUZZIFIER AND MEMBERSHIP FUNCTION

Fuzzifier is the mechanism that is used to map the real-world fuzzy inputs to the range [0, 1]. The membership function of a fuzzy set represents the degree of truth. Fuzzy truth represents membership in vaguely defined sets, not likelihood of some event or condition. In the membership function under consideration, the fuzzy inputs node residual energy, hop count and throughput have been divided into three fuzzy subsets - low, medium and high.

3.4 INFERENCE ENGINE AND FUZZY RULE BASE

The fuzzy inference engine takes the value of fuzzy inputs at each node and scans through the fuzzy rule base to find the appropriate entry corresponding to the fuzzy inputs to calculate the fuzzy output cost for each node.

3.5 DEFUZZIFIER

Defuzzifier produces a quantifiable result in fuzzy logic. Thus, defuzzifier produces a real-world output from the fuzzy outputs which are in the range (0, 1) by using defuzzification techniques.

4. CONSTRAINTS

In this paper, a fuzzy system is built over the AODV protocol with the following constraints:

4.1 NODE RESIDUAL ENERGY

The Node Residual Energy is defined as the minimum energy level of any node in the path.Every transmitted or received packet consumes power. Energy consumption due to transmission is greater than that of reception of packets. So, reliable and active nodes are subject to more power

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consumption as these nodes are more trusted for packet forwarding compared to their less reliable peers.

4.2 HOP COUNT

As the length of the route increases, the throughput achieved also reduces. So, it is required to ensure that the number of hops is not too high and the route chosen is also not much congested. This constraint is very important in WMN since here traffic is mainly directed towards the APs.

4.3 THROUGHPUT

Throughput is defined as the number of data packets transmitted by the sender and received by the receiver in a grant time. Thus, to a large degree, the performance of a network depends on throughput as we need each data packet to be transmitted successfully.

5. IMPLEMENTATION OF PROPOSED ROUTING SCHEME

Node residual energy, Hop count and Throughput are the three main parameters in this routing mechanism that make the routing scheme more and more reliable. Route Reliability evaluation function takes a number of input values based on twenty seven rules that dependent upon varied input variable values i.e. node residual energy, hop count and throughput. A fuzzy inference mechanism decides for each three input values which values appear in output. Absolute value of these three input parameters can take a large range on the network. So for each input parameter normalised values are considered.

Step 1:
"Crisp" normalized values have been converted into fuzzy variables. For this, three fuzzy sets have been defined for each variable (figure 2).
The fuzzy sets, for input variable 'Node Residual Energy' has been defined as low (from 0 to 0.4), medium (from 0.2 to 0.8) and high (from 0.6 to 1.0) (figure 3).
The fuzzy sets, for the input variable 'Hop Count' has been defined as low (from 0 to 0.4), medium (from 0.2 to 0.8) and high (from 0.6 to 1.0) (figure 4).
The fuzzy sets, for the input variable 'Throughput' has been defined as low (from 0 to 0.4), medium (from 0.2 to 0.8) and high (from 0.6 to 1.0) (figure 5).
The fuzzy sets, for the output variable 'Route Reliability' has been defined as low (from 0 to 0.4), medium (from 0.2 to 0.8) and high (from 0.6 to 1.0) (figure 6).

Step 2:
The normalized value of each parameter is mapped into the fuzzy sets in which each value will have some grade of membership function for each fuzzy set. The memberships of any particular input variable may vary in shape depending on the characteristic of the membership function used. In figure (3, 4, 5) it is shown that triangular membership function are used for input variables which in turn have same kind of properties.

Step 3:
Twenty seven fuzzy inference rules are derived for this proposed routing scheme as shown in table 1. The proposed fuzzy inference rules are used to find the reliable route for different ranges of the metric i.e. node residual energy, hop count and throughput. The output reliable routes are defined as low (from 0 to 0.4) which represent not reliable, medium (from 0.2 to 0.8) which represent better reliable route and high (from 0.6 to 1.0) which represent best reliable route from source to destination.

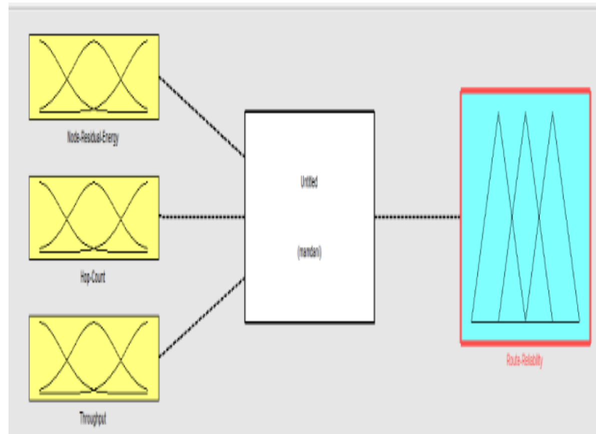

Figure 2: *Fuzzy mechanism for "Route Reliability" evaluation*

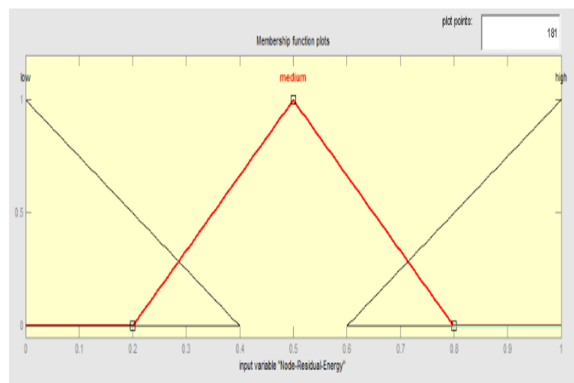

Figure 3: *Input variable "Node Residual Energy"*

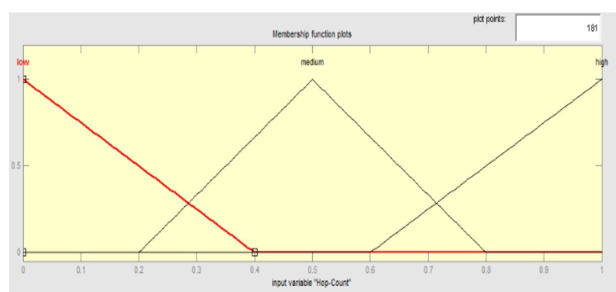

Figure 4: *Input variable "Hop count"*

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Table 1: *Fuzzy Rules*

S. No	Node Residual Energy	Hop count	Throughput	Route Reliability
1	Low	Low	Low	Low
2	Low	Low	Medium	Medium
3	Low	Low	High	High
4	Low	Medium	Low	Low
5	Low	Medium	Medium	Low
6	Low	Medium	High	High
7	Low	High	Low	Low
8	Low	High	Medium	Medium
9	Low	High	High	Medium
10	Medium	Low	Low	Medium
11	Medium	Low	Medium	Medium
12	Medium	Low	High	High
13	Medium	Medium	Low	Medium
14	Medium	Medium	Medium	Medium
15	Medium	Medium	High	High
16	Medium	High	Low	Low
17	Medium	High	Medium	Low
18	Medium	High	High	Medium
19	High	Low	Low	Low
20	High	Low	Medium	Medium
21	High	Low	High	Medium
22	High	Medium	Low	Low
23	High	Medium	Medium	Low
24	High	Medium	High	Medium
25	High	High	Low	Low
26	High	High	Medium	Medium
27	High	High	High	Medium

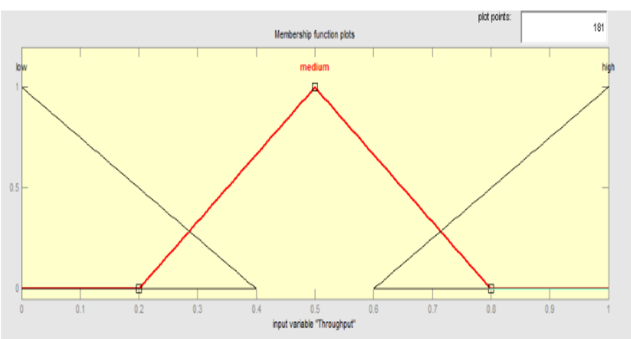

Figure 5: *Input variable "Throughput"*

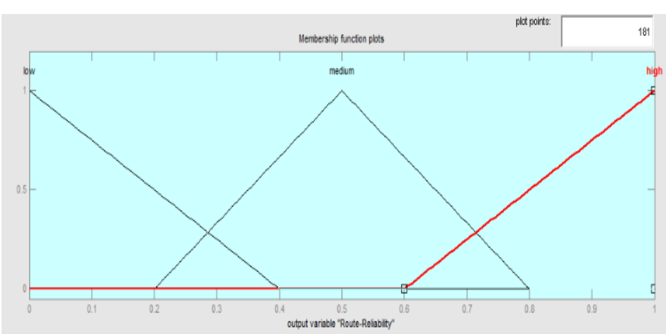

Figure 6: *Output variable "Route Reliability"*

3D decision surface has been used to show the routes based upon the rules mentioned in table 1.With the help of the following graphs in 3D decision surface routes are represented

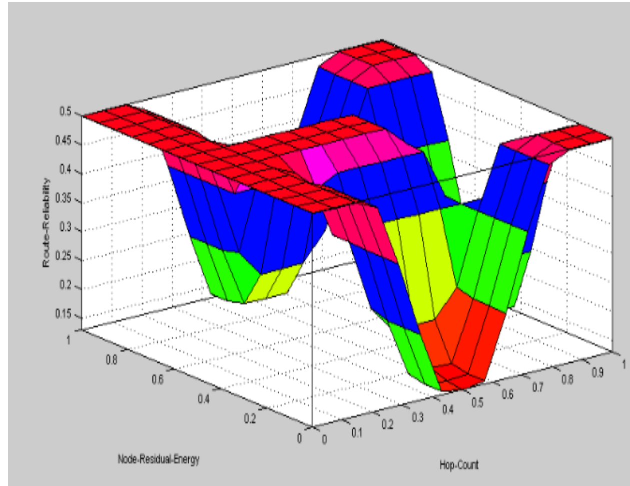

Figure 7: *'Route Reliability' O/P w.r.t. 'Node Residual Energy' and 'Hop Count'.*

In figure 7, the fuzzy input variable for the proposed routing scheme are Node residual energy and Hop count which lies on the horizontal axis and the output variable is route reliability which has been shown on the vertical axis. From the above figure it is clear that at low residual energy and low hop count the Route reliability is high, but if we increase the hop count then the route reliability also decreases and becomes medium. Finally at high hop count the route reliability will be low for constant node residual energy.

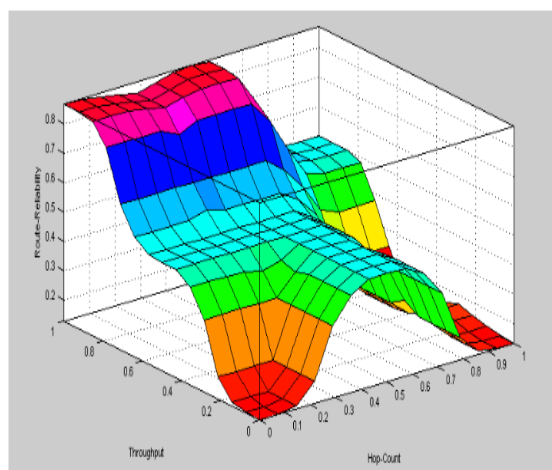

Figure 8: *'Route Reliability' O/P w.r.t. 'Throughput' and 'Hop Count'.*

In figure 8 the fuzzy input variable for the proposed routing algorithm are Throughput and Hop count which lies on the horizontal axis and the output variable is route reliability which has been shown on the vertical axis. From the figure it is clear that at high throughput and low hop count the Route reliability is high. , but if we increase the hop count then the route reliability decreases and becomes medium.

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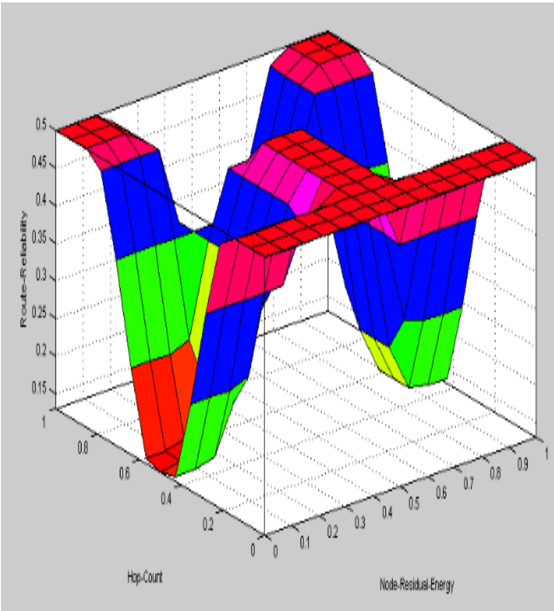

Figure9: *'Route Reliability' O/P w.r.t. 'Hop count' and 'Node Residual Energy'.*

In figure 9 the fuzzy input variable for the proposed routing algorithm are Hop count and Node residual energy which lies on the horizontal axis and output variable is route reliability which has been shown on the vertical axis.

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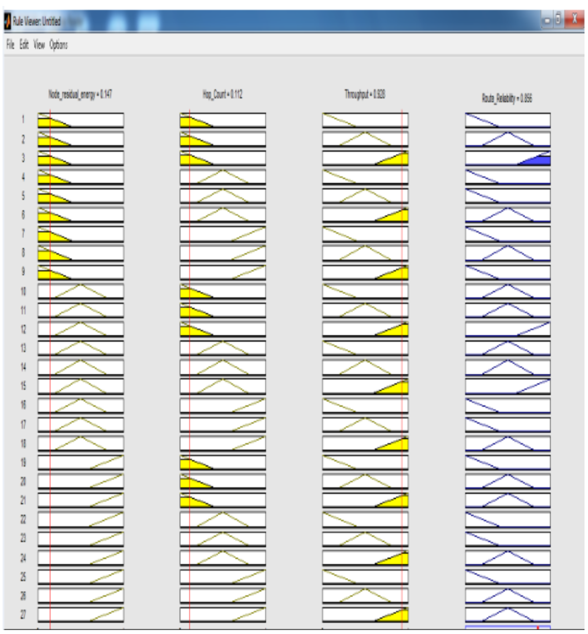

Figure 10: *'Route Reliability' O/P w.r.t. Low 'Node Residual Energy', Low 'Hop Count' and high 'Throughput'*

Figure 10 illustrates the test case when node residual energy is low (0.147), hop count is low (0.112) and throughput is high (0.928) then in this condition the route reliability is (0.856). So this algorithm works well when node residual energy and hop count are low.

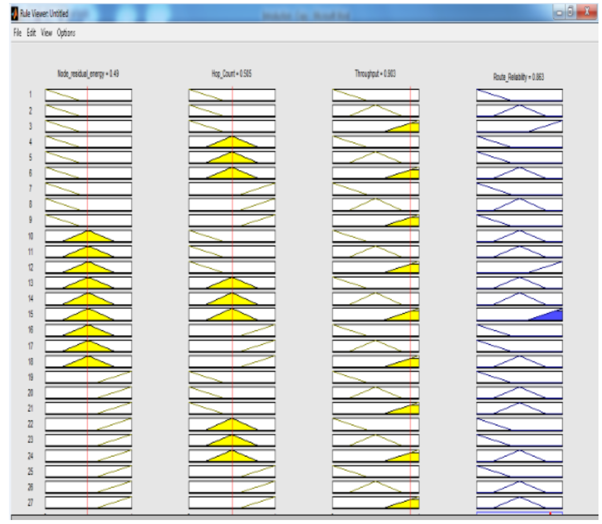

Figure 11: *'Route Reliability' O/P w.r.t. Medium 'Node Residual Energy', Medium 'Hop Count' and High 'Throughput'*

Figure 11 illustrates another test case if we increase the node residual energy towards medium (0.49),at medium hop count (0.505) and high bandwidth (0.903) the route reliability is again high (0.863). So this algorithm works well at medium hop count and node residual energy.

Figure 12: *'Route Reliability' O/P w.r.t. High 'Node Residual Energy', High 'Hop Count' and Low 'Throughput'*

This is very clear from the figure 12 that if we will increase the value of node residual energy (0.873) and hop count (0.908) to high and at low throughput (0.097) then the route reliability will be low (0.141)

6. SIMULATION RESULTS

- Simulation results show that the input variables lie on horizontal axis and the output variable route reliability lies on vertical axis in 3D decision surface. The proposed routing scheme works well if node

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residual energy is low, hop count is low and throughput is high.
- Route reliability is still high if node residual energy is low, throughput is high and hop count is increasing up to medium.
- On increasing node residual energy up to medium and hop count is also at medium then the route reliability is also high i.e. routing algorithm will works well at high throughput.
- When node residual energy is at medium and hop count is also at medium and throughput is decreasing from high to low then the route reliability is at medium.
- When node residual energy goes high and hop count is also high, and throughput is at low then the reliability goes from medium to low.
- At last, simulation results shows that proposed routing scheme works well at low node residual energy, low hop count, high throughput ; at medium node residual energy, low hop count, high throughput and at low node residual energy, medium hop count, high throughput.

7. CONCLUSION

Wireless mesh networks (WMN) are multi-radio, multi-hop networks with the ability of dynamically self organizing and self configuring.Due to the growth in the scale of WMNs new routing algorithms come into existence. This paper has proposed a new reliable and trusted routing scheme based on node residual energy, hop count and throughput. Our proposed scheme combines three parameters to discover a reliable route between the sources to destination. The experimental work indicates that the proposed routing scheme works well when node residual energy is low; hop count is also low and at high throughput. Simulation results indicate that proposed routing scheme has significant reliability enhancement as compared to other routing algorithms such as AODV. The simulation results show that our routing scheme is functional and effective.

8. FUTURE WORK

Routing is a multi constraint problem. In order to reduce congestion and make routing decisions more reliable, routing decisions should be based on more than one constraint. Fuzzy logic is a suitable tool to be applied in the wireless mesh network routing decision purposes. The research work in the present paper is to select reliable route by using certain metrics such as node residual energy, hop count and throughput. The proposed routing scheme maintains a reliable route from source to destination thus enhancing network life time and reduces number of dropped packets due to overloading and route stability during packet transmission. We believe that the proposed routing scheme can be further investigated based on other routing metrics in order to design better adaptive technique for wireless mesh networks

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