A Fuzzy Logic Based Network Dependent Routing Algorithm for Ad hoc Wireless Networks

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Abstract: The development of Mobile Ad Hoc network advocates self-organized wireless interconnection of communication devices that would either extend or operate in concert with the wired networking infrastructure or, possibly, evolve to autonomous networks. Unlike traditional wireless networks, ad hoc networks do not rely on any fixed infrastructure. Instead, hosts rely on each other to keep the network connected. One main challenge in design of these networks is their vulnerability to security attacks. Despite the existence of well-known security mechanisms, additional vulnerabilities and features pertinent to this new networking paradigm might render such traditional solutions inapplicable. In particular, the absence of a central authorization facility in an open and distributed communication environment is a major challenge, especially due to the need for cooperative network operation. In *MANET*, any node may compromise the routing protocol functionality by disrupting the route discovery process. In this paper, we understand the various routing problems related to bandwidth, signal power, mobility and delay. In this paper we are proposing a new routing algorithm that is totally network dependent and will remove the all routing problems

***Keywords*: Delay, Mobility, Mobile Ad hoc network, topology**

1. Introduction

Ad hoc networks are made up of a number of nodes, which are capable of performing routing without using a dedicated centralized controller as a base station. Ad hoc networks can be represented as a connected graph *G (v, e)*, with a set of vertices *v* and a set of edges *e*. Each vertex of the set v represents a network node and each edge of the set *e* represents a wireless link. The total number of nodes is $n = |v|$. This key feature of these networks enable them to be employed in places where an infrastructure is not available, such as in disaster and on battle grounds, or we can say that the dynamic nature of these networks and the scarcity of bandwidth in the wireless medium, along with the limited power in mobile devices (such as PDA's and laptops) make routing in these networks a challenging task. The topology of an ad hoc network changes due to the movement of mobile hosts, which may lead to sudden packet losses and delays. In the mobile ad hoc network due to the high mobility, low signal power and limited bandwidth the wireless links are frequently broken and new links are frequently established. Such dynamic network topology presents a significant challenge for the network routing algorithms. Several routing algorithms, such as shortest path routing algorithm like DBF were proposed for ad hoc wireless networks. But, these algorithms suffer from very slow convergence (the "routing to infinity" problem). Besides, DBF-like algorithms incur large update message penalties. Protocols that attempted to cure some of the shortcomings of DBF, such as Destination-Sequences Distance Vector routing were proposed.

However, synchronization and extra processing overhead are common in these protocols. Other protocols that rely on the information from the predecessor of the shortest path solve the slow convergence problem of DBF. However, the processing requirements of these protocols may be quite high, because of the way they process the update message. Realizations of the path findings algorithms, like the wireless routing protocol, are able to eliminate the "counting-to-infinity" problem and reduce the occurrence of temporary loops, often with less control traffic than traditional distance vector schemes. The main disadvantage of WRP is the fact that routing nodes constantly maintain full routing information in each network node, which was obtained as relatively high cost in wireless resources. In the Temporary Ordered Routing Algorithm the resulting route replies are also flooded, in a controlled manner, to distribute routes in the form of directed acyclic graphs (DAGs) rooted at the destination. In contrast, protocols such as Dynamic Source Routing and ad hoc on demand distance vector unicast the route reply back to the querying source, along a path specified by a sequence of node addresses accumulated during the route query phase. In the case of DSR, the node addresses are accumulated in the query packet and are returned to the source, to be used for source routing. AODV, on the other hand, distributes the discovered route in the form of next-hop information stored at each node in the route. These algorithms do not satisfy the requirements of an ad hoc wireless network completely and despite their shortcomings, these works lay the foundation for the development of our protocol. In this paper we propose a new routing protocol for ad hoc wireless networks, which address some of the problems with the existing approaches. In spite of all these improvements, the algorithm is simple as well as having low communication overhead and storage requirements. The algorithm has been simulated in MATLAB 7.2 in which we have uses the Fuzzy Logic tool kit.

The Fuzzy Logic is an innovative approach to help control non-repeating or unpredictable systems control accuracy. It uses a list of rules rather than complicated mathematical expression. Fuzzy Logic was introduced by L.A. Zadeh in 1965. Fuzzy Logic is also known as fuzzy rule based system and this is a non linear mapping technique of input data into output. Fuzzy Logic system is composed of five functional blocks.

2. The Proposed Routing Algorithm

Here Fuzzy Logic has been used for routing and management of an ad hoc wireless network. The proposed fuzzy logic based routing algorithm takes into account of three input variables, signal power and mobility and delay. The absolute value of each of these parameters can take a large range at different points on the network. We have considered the normalized values for each parameter. Now, 'crisp' normalized values are being converted into fuzzy variables. For this, three fuzzy sets have been defined for each variable. The sets, low (from 0 to 0.4), medium (from 0.2 to 0.8) and high (from 0.6 to 1.0) have been used for the input variable signal power (figure 1) and the sets, poor (from 0 to 0.4), average (from 0.2 to 0.8) and excellent (from 0.6 to 1.0) have been used for input variable delay (figure 2) and the sets, low (from 0 to 0.4), medium (from 0.2 to 0.8) and high (from 0.6 to 1.0) have been used for the input variable mobility (figure 3). The normalized value of each parameter is mapped into the fine sets. Each value will have some grade of membership function for each set. The memberships that have been defined for each of the fuzzy set for any particular input variable are triangular in shape. Next the rules of inference have been written. Initially total 27 rules were devised. The crisp value of input variable was given and a defuzzified crisp value for selected variable was calculated from the derived algorithm. An output linguistic variable is used to represent the route. Proposed optimal routes are based upon the fuzzy rules for different ranges of the metric availability. The routes (figure 4) are defined as below optimal (from 0 to 0.4), suboptimal (from 0.2 to 0.8) and optimal (from 0.6 to 1.0) between two mobile hosts. The below optimal indicates not optimal path, the sub optimal indicates good path and the optimal path indicates the best path. The proposed routing algorithm can apply to different routing metrics. These routes have to satisfy the mobility, signal power and delay requirements of the network. The grade of membership function can be any where between 0 and 1 for each fuzzy set. The defuzzified crisp value for selected variable was calculated from the derived algorithm. The proposed Fuzzy Logic & bandwidth based routing algorithm for ad-hoc wireless network is classified as "A Fuzzy Logic Based Network Dependent Routing Algorithm for Ad hoc Wireless Networks". This algorithm contains the following characteristics:

1. Freedom from loops: In the proposed algorithm the paths derived from the routing tables of all nodes have no loops.

2. Fast Route Convergence: The new routing protocol provides a new and stable route as soon as possible after a topology change.

3. Distributed Implementation: As we know those ad hoc networks are autonomous and self-organizing, this protocol is distributed in nature without relying on centralized authorities.

4. Entering/Departing nodes: This protocol is able to quickly adapt to entering or departing nodes in the network, without having to restructure the entire network.

5. On Demand operation: Since a uniform traffic distribution cannot be assumed within the network, the routing algorithm must adapt to the traffic pattern on a demand or need basis, thereby utilizing power and bandwidth resources more efficiently.

Our problem is to find the optimal and suitable route from source to the destination based on mobility, signal power and delay. The system is based on the fuzzy inference system. The major components of the system consist of the knowledge base, decision making, fuzzification and defuzzification. Now we will write the fuzzy rules based on the mobility, signal power and delay and try to find out the optimal path or route.

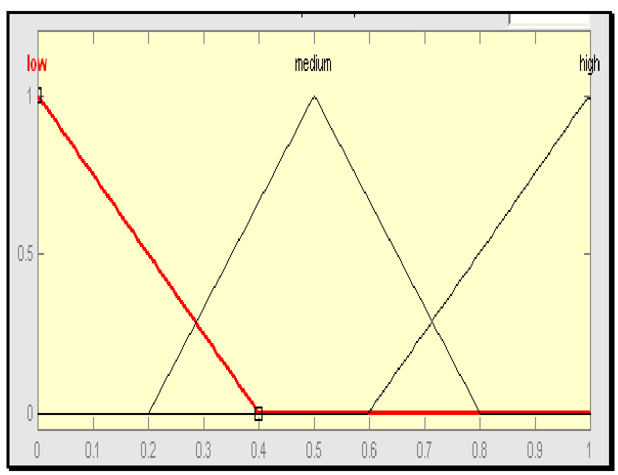

Figure 1. Input Variable 'Signal power'

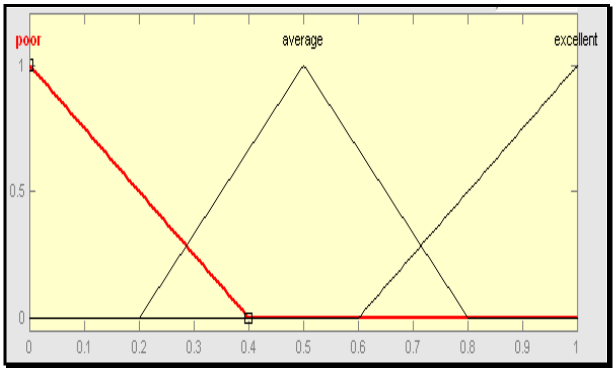

Figure 2. Input Variable 'Delay'

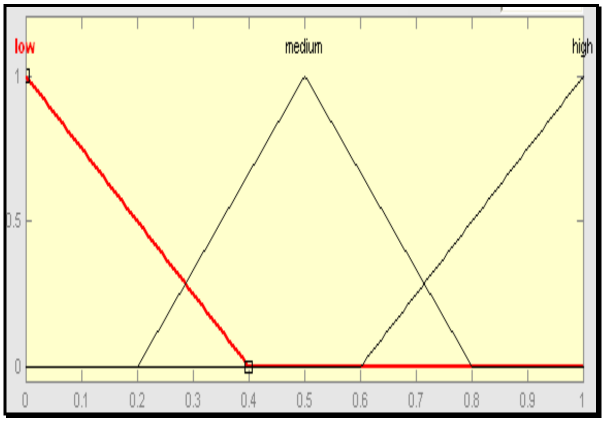

Figure 3. Input Variable 'Mobility'

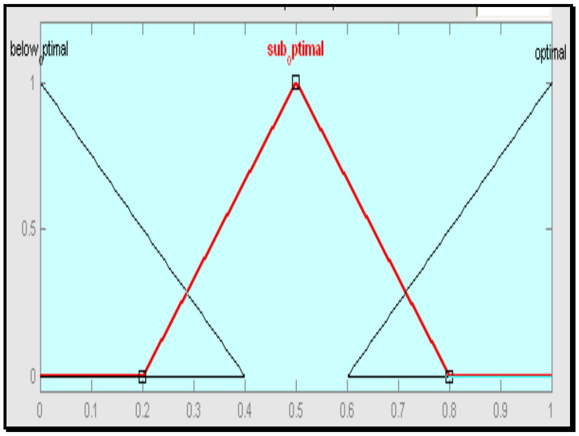

Figure 4. Output Variable 'Route'

The Fuzzy Inference rules for the proposed routing algorithm are following:

1. If (signal power is low) and (mobility is low) and (delay is poor) then the route will be below optimal.

2. If (signal power is low) and (mobility is low) and (delay is average) then the route will be below optimal.

3. If (signal power is low) and (mobility is low) and (delay is excellent) then the route will be sub optimal.

4. If (signal power is low) and (mobility is medium) and (delay is poor) then the route will be below optimal.

5. If (signal power is low) and (mobility is medium) and (delay is average) then the route will be sub-optimal.

6. If (signal power is low) and (mobility is medium) and (delay is excellent) then the route will be sub optimal.

7. If (signal power is low) and (mobility is high) and (delay is poor) then the route will be below optimal.

8. If (signal power is low) and (mobility is high) and (delay is average) then the route will be below optimal.

9. If (signal power is low) and (mobility is high) and (delay is excellent) then the route will be sub-optimal.

10. If (signal power is medium) and (mobility is low) and (delay is poor) then the route will be sub- optimal.

11. If (signal power is medium) and (mobility is low) and (delay is average) then the route will be optimal.

12. If (signal power is medium) and (mobility is low) and (delay is excellent) then the route will be optimal.

13. If (signal power is medium) and (mobility is medium) and (delay is poor) then the route will be below optimal.

14. If (signal power is medium) and (mobility is medium) and (delay is average) then the route will be sub optimal.

15. If (signal power is medium) and (mobility is medium) and (delay is excellent) then the route will be optimal.

16. If (signal power is medium) and (mobility is high) and (delay is poor) then the route will be below optimal.

17. If (signal power is medium) and (mobility is high) and (delay is average) then the route will be sub optimal.

18. If (signal power is medium) and (mobility is high) and (delay is excellent) then the route will be optimal.

19. If (signal power is high) and (mobility is low) and (delay is poor) then the route will be sub-optimal.

20. If (signal power is high) and (mobility is low) and (delay is average) then the route will be optimal.

21. If (signal power is high) and (mobility is low) and (delay is excellent) then the route will be optimal.

22. If (signal power is high) and (mobility is medium) and (delay is poor) then the route will be sub-optimal.

23. If (signal power is high) and (mobility is medium) and (delay is average) then the route will be sub-optimal.

24. If (signal power is high) and (mobility is medium) and (delay is excellent) then the route will be optimal.

25. If (signal power is high) and (mobility is high) and (delay is poor) then the route will be below - optimal.

26. If (signal power is high) and (mobility is high) and (delay is average) then the route will be sub-optimal.

27. If (signal power is high) and (mobility is high) and (delay is excellent) then the route will be optimal.

The routes based upon the above rules have been shown with the help of the following graphs:

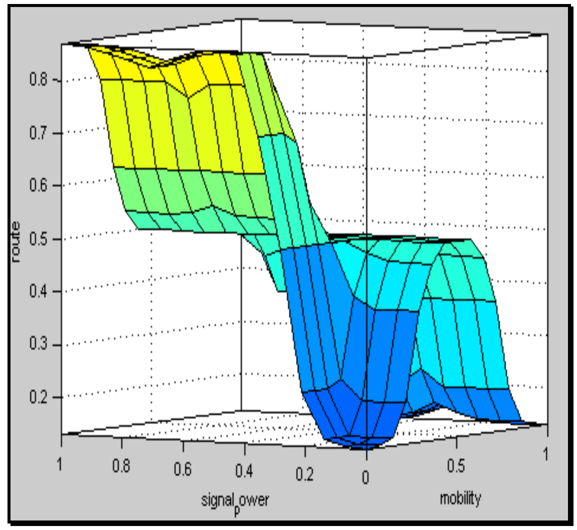

Figure 5. 'Route' O/P w.r.t. 'Mobility' and 'Signal Power'

In **figure 5** signal power and mobility are the fuzzy input variable for the proposed routing algorithm which lies on the horizontal axes and route is the output variable which has been shown on the vertical axis. It is very clear from the figure that at constant signal power and low mobility the Route is below optimal, but for any value of the signal power if we increase the mobility then the route also increases and becomes sub-optimal. Finally at high mobility the route will be below optimal for constant signal power.

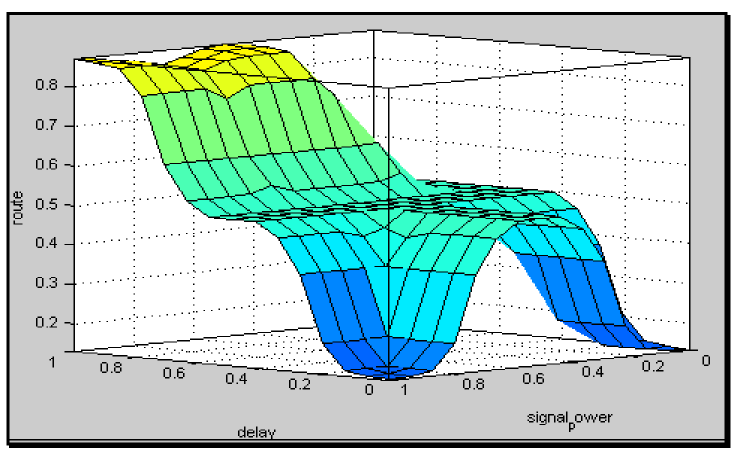

Figure 6 'Route' O/P w.r.t. 'Signal Power' and 'Delay'

In **figure 6** the inputs of the algorithm (signal power and delay) are on the horizontal axes and the output (route) is on the vertical axis. According to the figure It is clear that at constant delay and low signal power the route is below optimal but if the signal power is increased up to medium the route is sub optimal for poor delay. In the same way at high signal power and poor delay the route becomes below optimal. If delay is increased up to average at high signal power then the route is suboptimal but route becomes optimal at excellent delay and at high signal power.

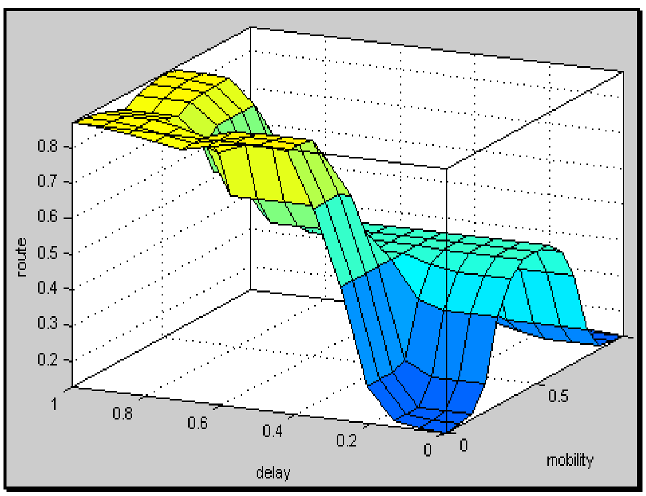

Figure 7. 'Route' O/P w.r.t. 'Mobility' and 'Delay'

In **figure 7** delay and mobility are the input variables and route is the output variable. The 3 D decision surface illustrate that route is below optimal for poor delay and low mobility. As the mobility is increased up to medium the route will be sub optimal. Again the similar process occurs and route is below optimal for poor delay. But as the delay becomes high, route increases up to sub optimality and optimality when the mobility is medium and high respectively.

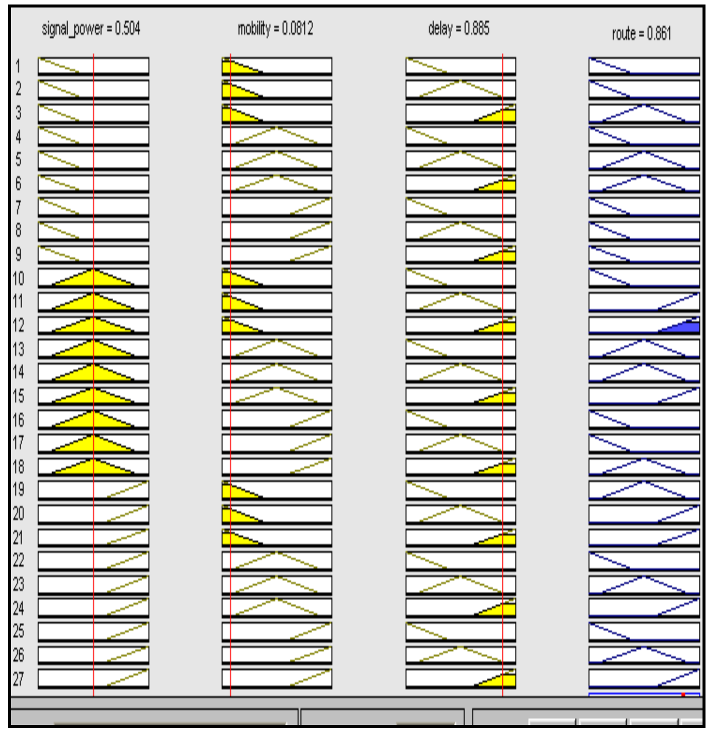

Figure 8. 'Route' O/P w.r.t. Medium 'Signal Power', Low 'Mobility' and Excellent 'Delay'

The **figure 8** illustrates that when signal power is medium (0.504), mobility is low (0.0812) and delay is excellent (0.885) then in this condition the route is optimal (0.861). So this algorithm works well when mobility is low and signal power is medium.

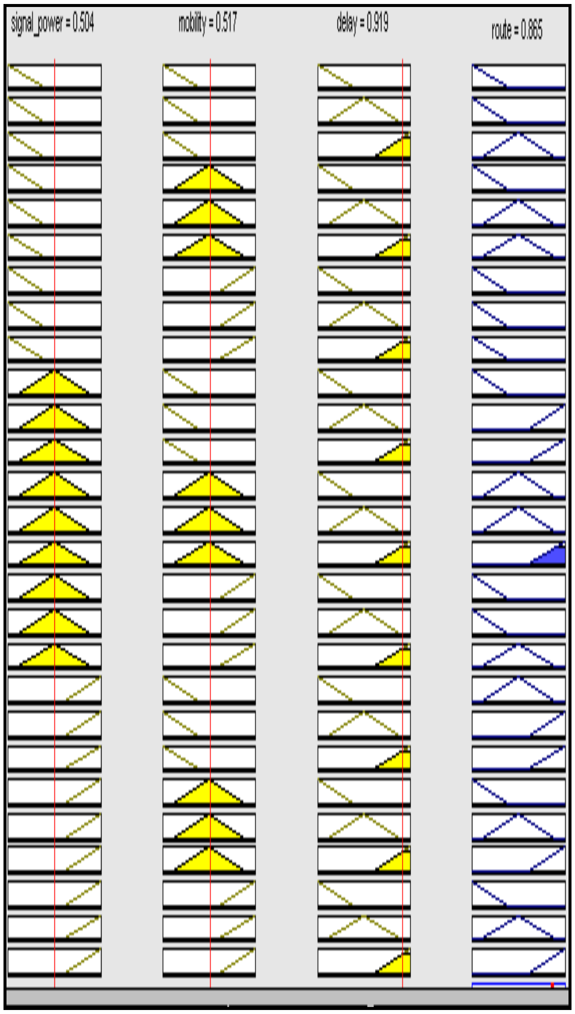

Figure 9. 'Route' O/P w.r.t. Medium 'Signal Power', Medium 'Mobility' and Excellent 'Delay'

In **figure 9** we have seen that route is optimal at low mobility, medium signal power and at excellent delay but against it when we increase the mobility towards medium (0.517) at medium signal power (0.504) and excellent delay (0.919) the route is again optimal. So this algorithm works well at medium mobility also.

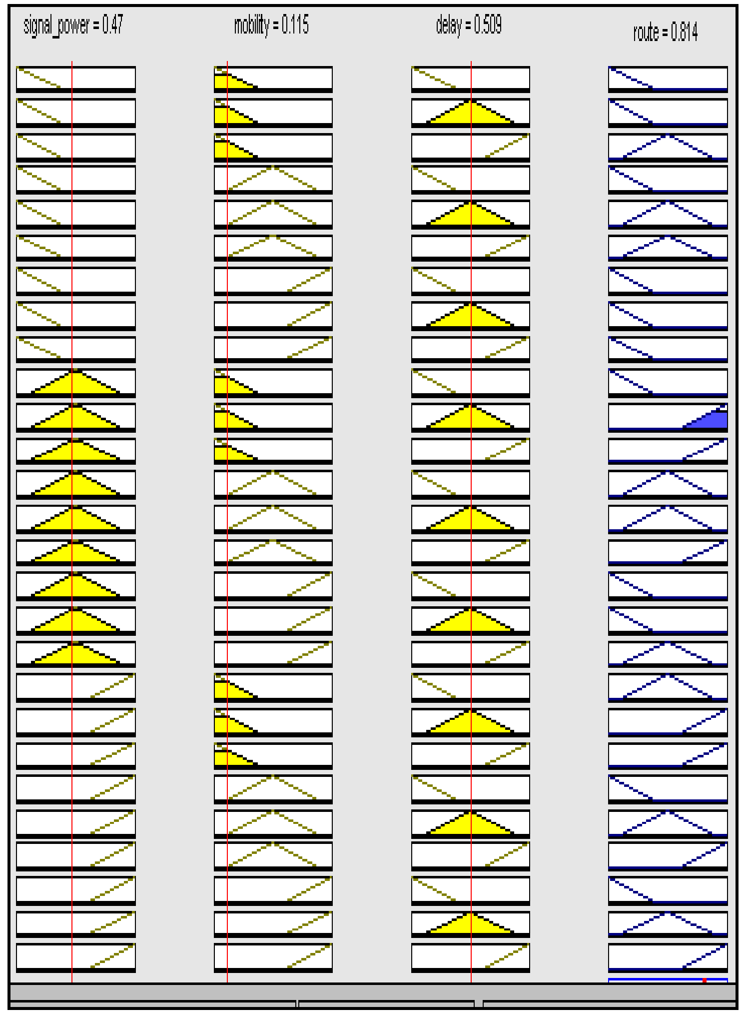

Figure 10. 'Route' O/P w.r.t. Medium ' Signal Power', Low 'Mobility' and Average 'Delay'

This is very clear from the **figure 10** that in this protocol the value of the signal power (0.47) and mobility (0.115) is same as in figure 6.8 but the difference is that when we will decrease the delay up to average (0.509) then the route is still optimal, but as we will increase the mobility then the route will be sub optimal.

3. Simulation Results

In decision surface (figure 5) the input variables signal power and mobility lie on horizontal axes and the output variable route lies on vertical axis. It shows that at constant signal power the route is below optimal for low mobility. But any signal power if we increase the mobility the route also starts increasing and becomes sub optimal. Finally when the mobility becomes high, the route will be below optimal for constant signal power. Now as we increase the signal power the route starts increasing towards optimality and becomes optimal for low and medium mobility. In figure 6 the inputs of the algorithm are on the horizontal axes and the output of the algorithm is on the vertical axis. Here, with the help of 3D surface we observe that at constant delay and low signal power the route is below optimal but if the signal power is increased up to medium the route is sub optimal for poor delay. Similarly at high signal power and poor delay the route becomes below optimal. It can also be observed that with average delay and high signal power the route is suboptimal and if we increase delay up to excellent the route is optimal at high signal power. In figure 7 the input variables mobility and delay lie at horizontal axes and the route at vertical axis. Here, we see that for poor delay and low mobility the route is below optimal. As the mobility increases and arrive up to medium the route will be sub optimal. Again the similar phenomenon occurs and route is below optimal for poor delay. But as the delay becomes high, route increases up to sub optimality and optimality when mobility is medium and high respectively. In figure 8 we see that at medium signal power (0.504), low mobility (0.0812) and excellent delay(0.885) the route is optimal (0.86) and as we increase the only mobility towards medium(0.517) then the route is again optimal (0.865) which has been shown in the figure 9. In figure 10, with medium signal power (0.47), low mobility (0.115) and average delay (0.509) the route becomes optimal again but as we increase the mobility then route becomes suboptimal.

4. Conclusions

Due to the unprecedented growth in the scale and diversity of mobile computing devices, new horizons for wireless connectivity has come into view. In this chapter, we have shown the importance of an ad hoc routing protocol and some of the previous works. Following that we have proposed our new routing protocol based on mobility, signal power and delay, where the segmentation of nodes will substantially reduce the overhead of the entire network and speed up the routing process. After fully describing its functions and mechanism, we have suggested various optimizations to the protocol and utilized the concept of stability index. Finally, we have done limited trials to show that our protocol is functional and effective; we do see the need in further experimentation in order to accurately access the practical effectiveness of our protocol in a medium to large size network.

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