International Journal of Control and Automation
Vol. 9, No. 8 (2016), pp.391-402
http//dx.doi.org/10.14257/ijca.2016.9.8.37

Fuzzy Optimized and Bee inspired Routing Protocol for Improved QoS in Mobile Ad Hoc Networks

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Abstract

As it is well aware, one of the major aspects of Ad Hoc networks is the randomized movement of nodes. In order for this to take place, the routing protocols in the Ad Hoc network have to quickly respond to the network topology change with the purpose of guaranteeing successful data packet delivery. This involves multiples routing pathways being established in order to improve on reliability and on limited bandwidth. The main idea behind the proposed algorithm is to apply the fuzzy modified Bee-MANET routing protocol on a simulated network and compare its efficiency with respect to Bee-MANET and AODV. Normally, the entire concept of the Bee-MANET routing protocol works on Swarm intelligence for choosing a path to send a packet from one node to another. The swarms of bees act as agents that communicate with each other via a 'dance', to select the shortest path i.e. the path that takes the least time based on the number of hops. However, a small modification has been made by applying fuzzy logic to alter the Bee-MANET routing protocol. Due to recurrent node movements, the topologies of mobile Ad-hoc networks keep changing rapidly. The fuzzy rules applied will dynamically decide upon the best path for the packet to be sent across. The swarm rules depend only upon the number of hops while the fuzzy rules consider a number of factors, including the number of hops as well as the energies of the nodes, bandwidth and data traffic. Ultimately, the aim of this work is to increase the Quality of Service (QoS) of the mobile Ad-hoc network by developing the efficiency with respect to latency and stability of the route.

Keywords*: Ad Hoc networks, routing protocols, Bee-MANET, AODV, Swarm Intelligence, Fuzzy logic, Quality of Service.*

1. Introduction

Wireless Networks is a type of network in which the participating systems can communicate with one another without the presence of a physical connection between them. Mobile Ad Hoc Networks (MANETs) is one broad category falling under Wireless Networks. MANETs have no specific base station. Each and every system can communicate with each other through different possible wireless transmission media (Example. Radio Waves). It has a continually varying infrastructure. Hence, its topology changes frequently. Hosts move and arrange themselves randomly, thus leading to unpredictable and untraceable topology changes. Due to unexpected packet congestion and the blockage of routes, providing a good QoS is highly challenging, mainly because of node mobility and lack of central coordination in the network.

Swarm Intelligence is an Artificial Intelligence technique, which is based primarily on the collective behavior of multiple, individual agents. These behaviors have been extracted from the actions of creatures that are present in nature such as bees and ants. These insects gather information based on simple, practical observations they make in their local environment. Bee-MANET is one such existing SI based routing protocol that

ISSN: 2005-4297 IJCA
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combines the interactive behavior of a group of honey bees while naturally searching for food and the common directions of a communication network. Although this protocol is dynamic, highly scalable and obtains an increased efficiency by reducing the number of hops traversed between the source and destination nodes, and reducing the number of control packets in the network, the route taken can be selected more efficiently by taking into consideration various other QoS parameters. Fuzzy logic can be used to implement these parameters while searching for a route and control the outcome to improve the QoS.

2. Literature Survey

Recently, various on demand protocols have been proposed due to their low routing overheads which in turn reduces the frequencies of route re-establishment and route queries. In such protocols we notice that routes are established between the source and destination only when the source demands.

GasimAlandjani [1] *et al*. first proposed Fuzzy Routing in Ad Hoc Networks where fuzzy logic was applied taking into consideration the importance of the routes and the network status. Several disjoint routes were empirically proven to increase reliability for a more important route. The proposed protocol was said to have provided higher reliability and lower delay when compared to the DSR and SMR protocol.

Bey-Ling Su [2] *et al.* proposed the Fuzzy Logic weighted multi-criteria for reliable multicast routing implemented using the fuzzy interference model. The inputs taken are sent controlled packets, number of hop counts and energy of the nodes is taken as the output. This protocol is compared with the conventional AODV protocol. Network Simulator 2 (NS2) has been used to evaluate its performance.

V.PonnyinSelyan [3] *et al.* has proposed an optimized AODV protocol for wireless networks where Ant Mesh Network for MANET is proposed. The AODV protocol has been modified with the Swarm Intelligence based Ant Colony Optimization to improve performance. The algorithm was simulated in NS2 and is found to have faster data transmission and less deadly compared to several other swarm intelligence protocols.

Pushpenderv[4] *et al.* has proposed an Agent Based scheme for Wireless Mesh Networks in which the fuzzy interference model has been used. The Mamdani method of fuzzy logic has been used with input as number of hops, bandwidth and packet loss rate and output being the delay. This model has been implemented using the Mamdani Toolbox present in MATLAB 7.0. In addition an Agent Based model with a number of mobile and static agents have been used to find a QoS aware path.

M.Sumathi[5] proposed the BeeIP protocol which is inspired from several ant colony optimisation protocols, in order to provide efficiency for multicast routing in MANETs using bee colony optimisation principles. The adopted methods of

PrakirtiRaghuvanshi [6] et al. proposed an agent based approach for routing in Ad hoc networks. The proposed approach was a modification to the AODV protocol where agents were used to discover new routes and update them as well as look up at the newly discovered routes of other agents. A mobile agent format is elucidated to help in this process, and is said to provide better throughput and less delay than AODV.

D.Karaboga [7] et al. proposed the ABC algorithm which uses the concepts used by bees to discover food sources. The algorithm employs employed bees, onlookers and scouts for food discovery. While a single employed bee was allotted to a single food source, this employed bee gives food source information to the onlooker. If a food source isn't found the employed bee turns into a scout and searches for a food source. The proposed algorithm was found to be very effective and performed better than the differential evolution, particle swarm and evolutionary algorithm.

D.Choudhary[8] proposed a Bee-Inspired routing protocol known as the Bee Ad Hoc routing protocol for MANETs where two bee agents have been used - the scout bee to

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discover routes and the forager bee to transport data. The Bee Ad Hoc algorithm has been proved to be energy efficient.

Z.Albayrek [9] *et al.* proposed the BEE-MANET has been proposed as an extension to the Bee Ad Hoc Protocol. This protocol reduces the number of control packets in the network compared to the Bee Ad Hoc with the help of Accumulators. This protocol has been compared to the AODV and the Bee Ad Hoc protocol using two performance metrics - Throughput and Average end to end delay. Simulation results have been measured using Network Simulator 2 (NS2) which finally shows that BEE-MANET produced better results in terms of throughput in comparison to the other two protocols.

While the above algorithm successfully reduces the number of control packets ion the network, it fails to take care of various other parameters like energy, throughput and delay.

3. Routing Protocols

Over several years, various routing protocols have been proposed for Wireless Ad Hoc Networks. We can classify these protocols into two types: On demand protocols and protocols that require routing table at each node or table-driven routing protocols. On demand routing protocols do not have a routing table at each node. As the nodes keep moving and the network dynamically changes, a route is established on demand and this route is alive till data is transferred completely between source and destination. On the other hand, in table- driven routing protocols, routing tables are placed at each node and the new routes keep getting updated in the routing table present at each node as the nodes move dynamically.Over the years, several routing algorithms have been designed taking into account the collective behavior of social insects and other animals [7]. Two such swarm intelligence based honey bee routing protocols that have served as the basis for the proposed protocol are elucidated as follows:

3.1.Bee Ad Hoc Routing Protocol

Bee Ad Hoc is a multi-path routing algorithm for MANETs which works on using the intelligent principles that Bee's use. The algorithm employs the characteristics of scout bees for route discovery and forager bees for packet delivery along with the waggle dance of the bees to discover the most optimal path. The algorithm employs a very simple architecture consisting of the packing floor, dance floor and the entrance as shown in Figure 1. The entrance floor is an interface to the lower MAC layer, while the packing floor is an interface to the upper transport layer [8]. The dance floor forms the heart of the entire protocol as it maintains the list of active foragers and the routes to active destinations. For a route that is inactive, scout bees work on the principle of broadcast to discover a route to the destination. The Bee Ad Hoc Algorithm was developed to gain efficiency by making optimal use of the battery of the nodes by employing a mechanism to deliver data through different routes rather than on the best route [8].

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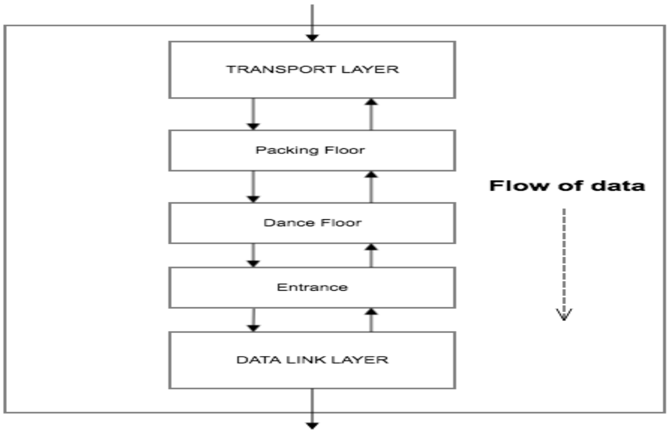

Figure 1. Architecture of the Bee Ad Hoc protocol

3.2.Bee MANET Routing Protocol

The Bee-MANET Protocol was proposed as an improvement to the Bee Ad Hoc protocol with the aim or reducing the number of control packets in the network. This protocol made use forward and backward agents for route discovery and achieved its goal using an accumulator. While the routing process remains similar to that of the Bee Ad Hoc protocol, the difference comes into play by broadcasting the accumulator instead of individual scout agents during the route discovery process. The accumulator consists of a buffer of scout agents that are arriving from neighboring nodes. This accumulator is created at every node in the network.

4. Motivation

Ad Hoc Networks are highly dynamic in nature with highly unstable routes between the source and the destination. While Swarm Intelligence based protocols like the Bee MANET have proven to find more stable and efficient routes with respect to the number of hops and the number of control packets in the network, there is still some uncertainty in the network mainly due to variable position of the nodes. Fuzzy Logic could be used to overcome this uncertainty to a large extent using numerous fuzzy rules along with the appropriate membership function and model the inexact nature of human decision-making based on imprecise data. While the above algorithm successfully reduces the number of control packets ion the network, it fails to take care of various other parameters like delay.

5. Research Problem

The Bee inspired routing protocols are not commonly used protocols, and while it does perform better than most other MANETs, one of the major drawbacks that we have tried to fix is the latency delay and reliability. High latency delay and lack of reliability could cause the system to break down and lose sensitive information, which is highly unwanted. Hence, this paper was projected to focus on certain parameters like route stability that normally, have not been given any importance in the existing Bee MANET protocol.

6. Methodology

Primarily, all the nodes in the network keep moving randomly which in itself causes a high level of uncertainty. Now, suppose we need to send a message from a source node to a destination node, a packet is firstly sent to all nodes that are adjacent to the source node, i.e., the first level of nodes. All the data about these nodes such as the node energy, traffic and bandwidth is obtained through the packets (scout bees). Consequently, packets are

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further forwarded to all the nodes which are adjacent to these nodes, i.e., the second level of nodes. As a result, the data about these nodes is also obtained with the help of the packets. This process is continuously repeated, until the destination node is reached. However, if the number of nodes in the network is high, then this procedure can cause a tremendous amount of data traffic to be generated in the system, which will inadvertently lead to an increased delay. Hence, the concept of an accumulator is employed in each node. Each node has an accumulator for itself which stores the packet and the node it was sent from. This way, only the first packet that reaches the node is saved as it took the shortest path to reach that node. Ultimately, when the packet reaches the final node, the accumulator provides us with a scheme through we can track the packet back to the source node via the shortest available path. After the scout bee reaches the source node, the membership function is used to look after fuzzification of the data obtained by the various scout bees. Once fuzzification takes place, the effects of the various parameters on the network are mapped and compared after which the most optimal path is obtained with respect to the number of hops, as well as, with respect to other parameters in the latency, stability of the route and node energy. Hence, this will help us to acquire the finest path and thus, achieve optimality not only with respect to delay, but also, with respect to the stability of the network. This system can also work for more than one source or destination node. Therefore, by employing all these techniques, this system gains an improved efficiency, and the Quality of Service, as a whole, escalates significantly. Diagram 1 shows the flow of the proposed protocol.

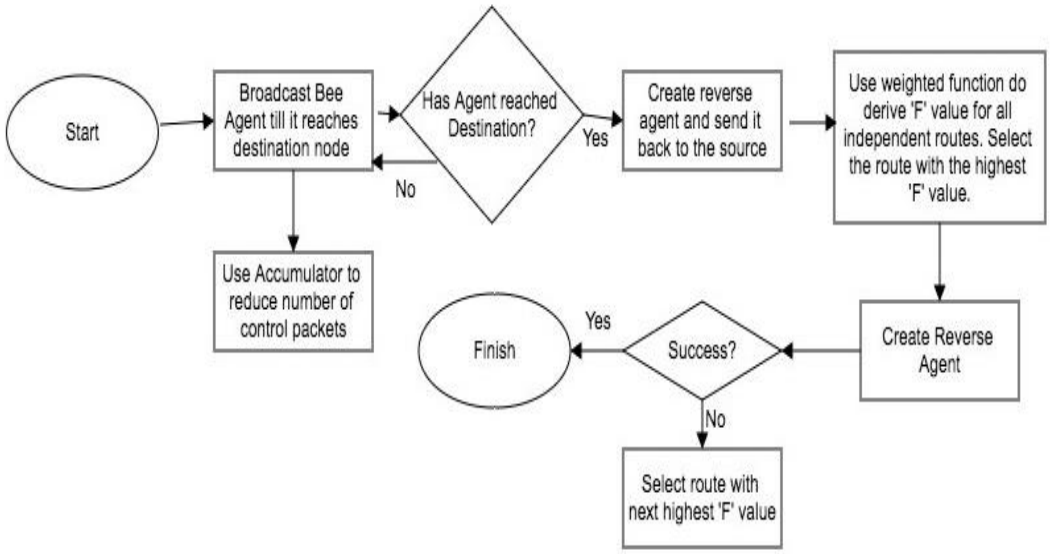

Diagram 1. Complete Flow of the ABAODV Routing Protocol

7. The Proposed Fuzzy Model

This section discusses the architecture of proposed fuzzy system. The fuzzy model was selected because of its various advantageous like, flexibility, tolerance to imprecise data and ability to be built on top of experience of experts over other systems.

7.1.Fuzzy Inputs

In order to decide which route to select, the following parameters which are collected by the backward scout bee while traversing back to the destination, are considered:

Latency: It is the amount of time taken by the scout bee to traverse back to the destination. The time taken into account begins once it is broadcasted from the source.

Latency subtly takes care of the number of hops traversed. The linguistic values of latency varies as High, Medium and Low as seen in Equation 1. The range of the parameter is [0, 60] m/s as shown in Figure 2.

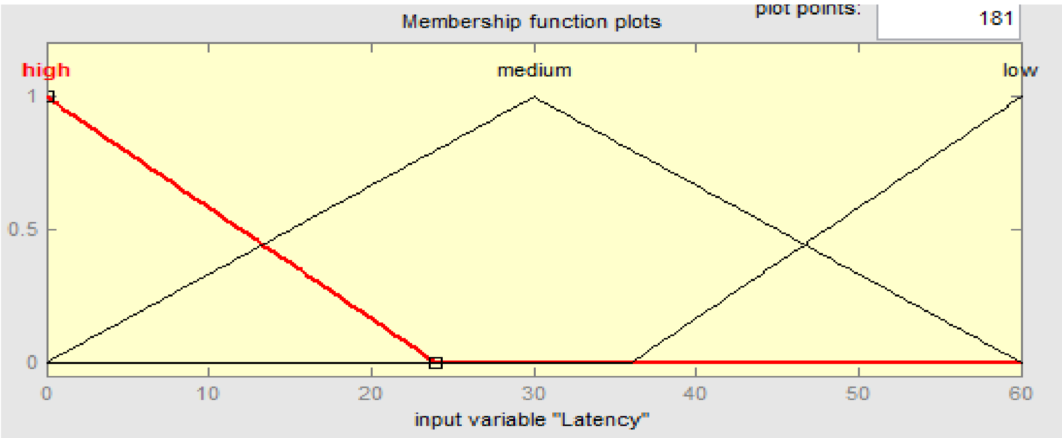

Figure 2. Membership Graphic for the Latency Fuzzy Variable with Three Fuzzy Numbers Low, Medium and High

$$\mu_{high} = \begin{cases} \frac{x}{24} & 0 \leq x < 24 \\ 0 & 24 \leq x \end{cases} \qquad \mu_{medium} = \begin{cases} \frac{x}{30} & 0 < x < 30 \\ \frac{60-x}{30} & 30 \leq x < 60 \end{cases} \qquad \mu_{low} = \begin{cases} 0 & x \leq 36 \\ \frac{x-36}{24} & 36 \leq x < 60 \end{cases}$$

Equation 1.Membership Functions for Input Parameter Stability

Equation 1 show the membership functions for Route Stability. In Equation 1, membership functions for poor, moderate and excellent is described. Triangular membership functions are used to define this input parameter. For excellent, below 0.6 the function is zero and gradually increases to 1. For poor, the value decreases gradually till 0.4 and then stays 0, and for moderate the membership value increases gradually till 0.5 and then decreases with same slope.

Hop Count: It is the number of intermediate nodes between the sender and destination. The linguistic values of this parameter are: very high, high, medium, low and very low. The range for this parameter is [0-15].

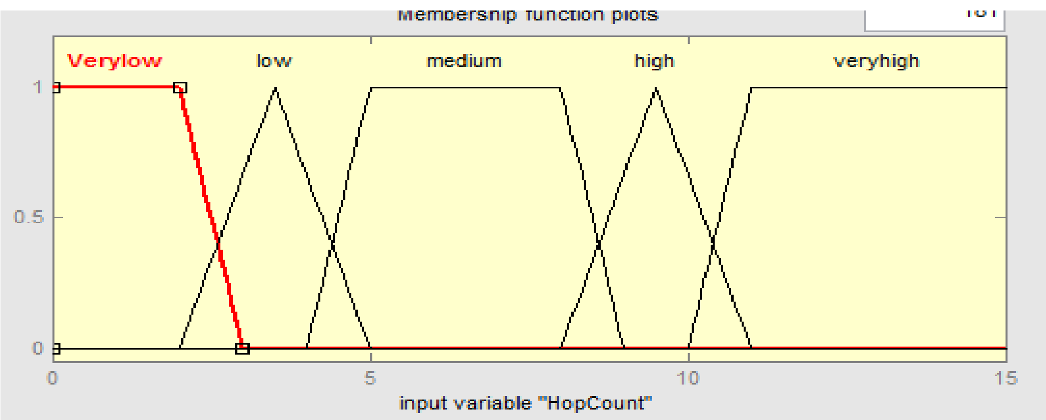

Figure 3. Membership graphic for the Hop Count variable with five fuzzy numbers Very Low, Low, Medium, High, and Very High

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$$\mu_{verylow}=\begin{cases}1 & x<2\\ \frac{3-x}{1} & 2\le x<3\\ 0 & x\ge 3\end{cases}$$

$$\mu_{low}=\begin{cases}0 & x<2\\ \frac{x-2}{1.5} & 2\le x<3.5\\ \frac{5-x}{1.5} & 3.5\le x<5\\ 0 & x\ge 5\end{cases}$$

$$\mu_{medium}=\begin{cases}0 & x<4\\ \frac{x-4}{1} & 4\le x<5\\ 1 & 5\le x<8\\ \frac{9-x}{1} & 8\le x<9\\ 0 & x\ge 9\end{cases}$$

$$\mu_{high}=\begin{cases}0 & x<8\\ \frac{x-8}{1.5} & 8\le x<9.5\\ \frac{11-x}{1.5} & 9.5\le x<11\\ 0 & x\ge 11\end{cases}$$

$$\mu_{veryhigh}=\begin{cases}0 & x<10\\ \frac{x-10}{1} & 10\le x<11\\ 1 & x\ge 11\end{cases}$$

Equation 2.Membership Functions for Input Hop Count

Figure 3 and Equation 2 show the membership functions for Hop Count. In Equation 2, membership functions for very low, low, medium, high and very high is described. Trapezoidal membership functions are used to define this input parameter.

Node Energy: It is the amount of power level of node. The greater the node energy, the greater the possibility of route getting selected. The linguistic values are: very high, high, medium, low and very low.

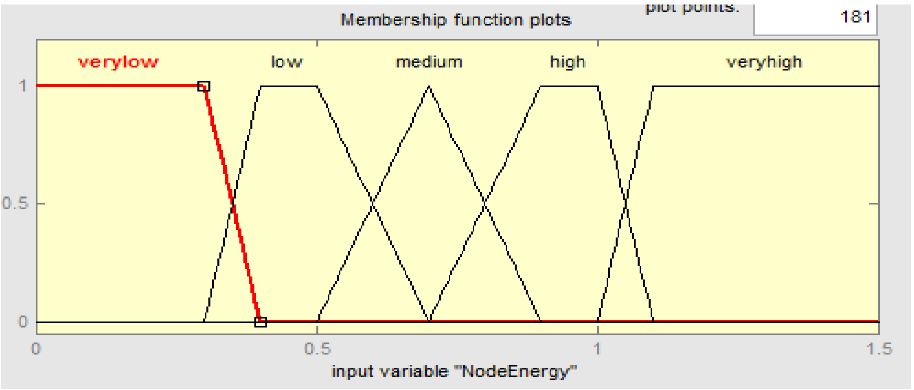

Figure 4. Membership Graphic for the Node Energy Variable with Five Fuzzy Numbers Very Low, Low, Medium, High, and Very High

$$\mu_{veryhigh}=\begin{cases}0 & x<1\\ \frac{x-1}{0.1} & 1\le x<1.1\\ 1 & x\ge 1.1\end{cases}$$

$$\mu_{high}=\begin{cases}0 & x<0.7\\ \frac{x-0.7}{0.2} & 0.7\le x<0.9\\ 1 & 0.9\le x<1\\ \frac{1.1-x}{0.1} & 1\le x<1.1\\ 0 & x\ge 1.1\end{cases}$$

$$\mu_{medium}=\begin{cases}0 & x<0.5\\ \frac{x-0.7}{0.2} & 0.5\le x<0.7\\ \frac{0.9-x}{0.2} & 0.7\le x<0.9\\ 0 & x\ge 0.9\end{cases}$$

$$\mu_{low}=\begin{cases}0 & x<0.3\\ \frac{x-0.4}{0.1} & 0.3\le x<0.4\\ 1 & 0.4\le x<0.5\\ \frac{0.7-x}{0.2} & 0.5\le x<0.7\\ 0 & x\ge 0.7\end{cases}$$

$$\mu_{verylow}=\begin{cases}1 & x<0.3\\ \frac{0.4-x}{0.1} & 0.3\le x<0.4\\ 0 & x\ge 0.4\end{cases}$$

Equation 3.Membership Functions for Input Node Energy

Figure 4 and Equation 3 show the membership functions for Node Energy. In Equation 3, membership functions for very low, low, medium, high and very high is described. Trapezoidal membership functions are used to define this input parameter.

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7.2.Fuzzy Output

The weights of all the rules are taken as one, which is mentioned at the end of each rule. All the fuzzy rules used by the system are listed follow:

Table 1.Fuzzy Rules

If (HopCount is veryhigh) then (RouteSelected is Discard) (1)
If (HopCount is high) then (RouteSelected is Discard) (1)
If (HopCount is medium) then (RouteSelected is Selected) (1)
If (HopCount is low) then (RouteSelected is Selected) (1)
If (HopCount is verylow) then (RouteSelected is Selected) (1)
If (NodeEnergy is veryhigh) then (RouteSelected is Selected) (1)
If (NodeEnergy is high) then (RouteSelected is Selected) (1)
If (NodeEnergy is medium) then (RouteSelected is Discard) (1)
If (NodeEnergy is low) then (RouteSelected is Discard) (1)
If (NodeEnergy is verylow) then (RouteSelected is Discard) (1)
If (Latency is high) and (Stability is Poor) then (RouteSelected is Discard) (1)
If (Latency is medium) and (Stability is Poor) then (RouteSelected is Discard) (1)
If (Latency is low) and (Stability is Poor) then (RouteSelected is Discard) (1)
If (Latency is high) and (Stability is Excellent) then (RouteSelected is Selected) (1)
If (Latency is medium) and (Stability is Excellent) then (RouteSelected is Selected) (1)
If (Latency is low) and (Stability is Excellent) then (RouteSelected is Selected) (1)
If (Latency is high) and (Stability is Moderate) then (RouteSelected is Selected) (1)
If (Latency is medium) and (Stability is Moderate) then (RouteSelected is Discard) (1)
If (Latency is low) and (Stability is Moderate) then (RouteSelected is Discard) (1)

7.3.Fuzzy Inference

Based on these input parameters, Fuzzy logic rules are formulated to decide whether a route is to be selected or discarded. These rules depend on the priority given for the application that the routing protocol is put into use. In certain applications, latency might be given a higher priority while in others a higher stable route is given higher priority. The rules are expressed in Mamdani Form, where latency, stability and status of the route are considered as linguistic variables that signifies four input variables and one output variable respectively.

De-Fuzzification method used is centroid method. MATLAB FIS editor to select hop count, node energy and stability and use Mamdani Inference system to get route selected as our output. "AND" method used is min(minimum), "OR" method used is max(maximum), implication method used is min(minimum) and Aggregation method used is max(maximum).

Membership Value (F) =w1*(Latency)+ w2*(Route Stability)+w3*(Hop Count)+w4*(Node Energy)

Where w1, w2, w3 and w4 are the weightages assigned depending upon the requirements and the priorities of the application in which the routing protocol is being deployed. The overall architecture of the system is shown in Figure 5.

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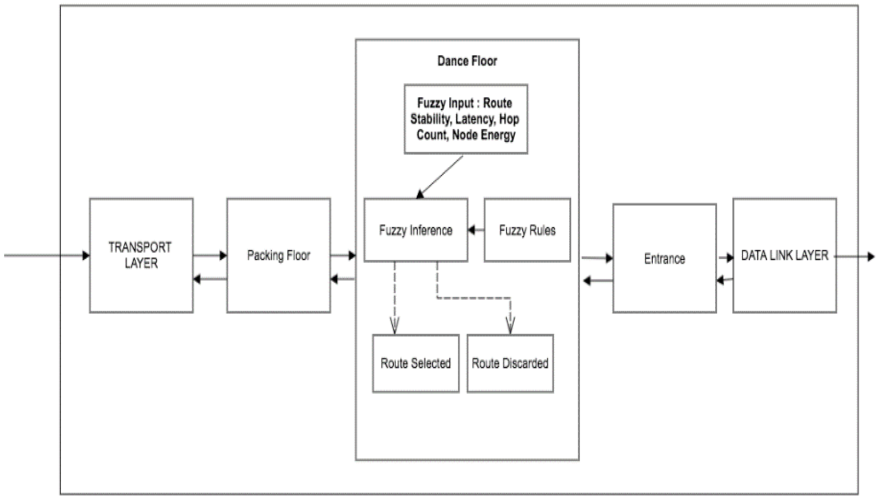

Figure 5.Architecture of the Fuzzy Optimized Bee Inspired Routing Protocol

7.4.Results

The proposed system was implemented on MATLAB and the results are tabulated below:

Table 2.Results of Fuzzy Inference System implemented on MATLAB

Serial Number	Hop Count	Node Energy	Latency	Stability	Route Selected (Fuzzy value)	Route Selected (Y/N) [threshold=0.5]
1	1	0.335	5	0.05	0.513	Y
2	2	0.45	15.9	0.05	0.5	Y
3	5	0.88	15.9	0.269	0.49	N
4	9	1.28	15.9	0.269	0.56	Y
5	13	0.15	39.5	0.269	0.33	N
6	13	0.15	56	0.777	0.417	N
7	8	1.5	15	0.223	0.526	Y
8	4	1.5	15	0.223	0.582	Y
9	1	1.49	60	0.946	0.66	Y
10	4	1.4	33	1	0.64	Y
11	13	0.813	40.7	0.153	0.448	N
12	2	0.624	1.58	0	0.477	N
13	1	0.561	1.58	0.321	0.527	Y
14	1	1.48	43.3	0.774	0.58	Y
15	11	0.529	43.3	0.774	0.415	N

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7.5.Control Surface of Route Stability

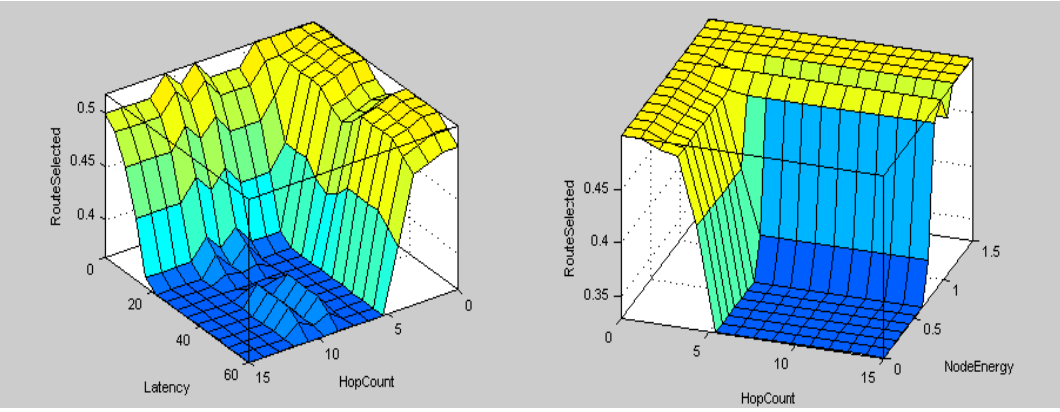

Figure 6. Control Surface of the Route Selected Fuzzy Variable for the Proposed Fuzzy System over the Two Fuzzy Input Variables (i) Latency and Hop Count (ii) Hop Count and Node Energy

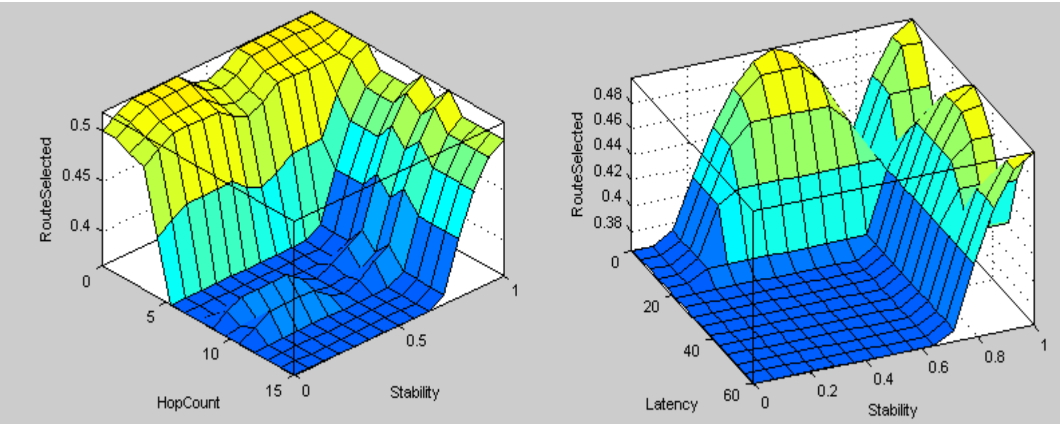

Figure 7. Control Surface of the Route Selected Fuzzy Variable for the Proposed Fuzzy System over the Two Fuzzy Input Variables (i) Stability and Hop Count (ii) Latency and Stability

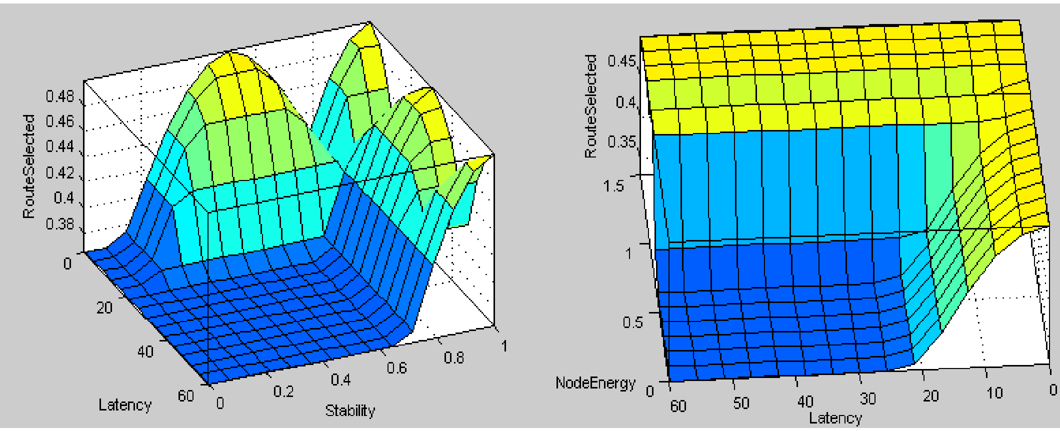

Figure 8. Control Surface of the Route Selected Fuzzy Variable for the Proposed Fuzzy System over the Two Fuzzy Input Variables (i) Latency and Stability (ii) Latency and Node Energy

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Figure 6 show the control surface of fuzzy output variable route selected against the input variables Hop Count, Latency and Node Energy. Similarly, the Figures 7 and 8 show the control surface of route selected against the input variables Latency, Stability, Node Energy and Hop Count. In figure 8 the second graph shows the curve dips from zero to twenty, because the latency increases which decreases the probability of route selected to decrease. Similarly, in figure 6, the second graph, the decrease in route selected is accounted by the number of hop count. The hop count, when increased the probability should go down for route selected. Other graphs display the route selected with other input parameters.

8. Applications

The proposed can also be extended to VANETs. Vehicular Ad-Hoc networks, being an instance of MANETs that establish wireless connections between cars, requires reliable packet transmission but faces a lot of problems regarding rapid topology changes and frequent disconnections which makes it difficult to design an efficient routing protocol for this purpose. There is a necessity for warning messages to be communicated between cars more efficiently, and at the same time, by increasing dependability. We believe that the Bee swarm intelligence algorithm along with fuzzy logic which helps in reducing uncertainty, also helps to improve on the problems mentioned above with fuzzy parameters. Furthermore, this algorithm has military applications as the random movement of nodes could resemble navy ships or the aircrafts. The main use of this protocol in the military is that it has a lack of infrastructure and that it can get around a single point of failure, thus fulfilling the military’s primary requirement, reliability.

9. Conclusion

We have proposed a routing protocol based on fuzzy roles and swarm intelligence in Wireless Ad-Hoc networks. The fuzzy logic along with the Bee inspired protocol that has been introduced in this paper, helps to further reduce uncertainty in the Ad-Hoc network and achieve improved QoS through reduced delay, increased throughput and better reliability. Choosing an energy efficient path helps to additionally reduce delay and produces an effective communication path. Future work may include the implementation of the proposed scheme using a suitable tools for simulating the network and applying fuzzy logic.

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