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RESEARCH ARTICLE

Selecting Optimal Path in Multiple-Path Routing for MANETs Using Fuzzy Cost

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Abstract

Background/ Objectives: Mobile Ad Hoc Networks (MANETs) consists of a set of nodes, where the nodes tend to change their positions time to time because of their infrastructure less characteristic. In MANETs, the protocol that is considered to be the appropriate for constructing an efficient route is AODV. Broadcast storm is another approach that can be used for establishing a path between the sender and receiver. Due to the concerns related to contention and collision, broadcast is not considered as an efficient mechanism for path selection. Though the aim of broadcasting is to minimize the flooding other issues like bandwidth consumption, collision and contention cannot be controlled. Since MANETs are associated with inadequate bandwidth, the approach of broadcasting is not efficient. Multipath routing approach permits in constructing multiple paths between the communicating nodes (sender and receiver). This approach is complicated due to the problem of node mobility in MANETs. The other paths available are not reliable because of the ad hoc nature of MANETs. The intention is to design a fuzzy controller that assists in reducing the reconstruction of paths using fuzzy cost assigned to each node in the network. **Methods:** The concept of this paper is to establish an optimal path from sender node to the receiver node from the available multiple paths in MANETs. The path established in this approach uses fuzzy cost. Fuzzy measure is the criteria used for establishing a path. The concept ImRMR used in this paper has been included with few improvements. The basic functionality of ImRMR is that paths are classified based on rank fitness. The proposal is to classify the paths based on its fuzzy cost. This fuzzy cost classifies the paths fitness. **Findings:** The proposed fuzzy cost approach discussed in this study is compared with On-Demand Multicast Routing Protocol (ODMRP). The result exhibits that the proposed method works better under differing conditions like traffic load, transmission range between nodes and also considers node mobility. The proposed mechanism with inclusion of fuzzy cost shows 5% energy efficiency, reduces the collisions by about 35% and throughput is enhanced by 30%. There has been a considerable decrease in the number of queries by 23%. The simulation results indicate that ODMRP with fuzzy cost is more useful and significant. Hence, consideration of fuzzy cost as a means for selecting an effective route is assumed to be the best. **Novelty:** This method contributes in reducing the drawbacks of routing approaches whether it is unipath and multi-path approach. The proposed approach changes the value of the attributes for a given route with fuzzy cost. A threshold value will be considered initially and the route having a cost more than the initialized threshold would be advised as the best route. This route would be considered as the efficient route for transmission between the sender and the receiver.

Keywords: Unipath; multiple paths; Fuzzy cost; Fuzzy fitness; Rank fitness

1 Introduction

The most insecure network for transmission is Mobile Ad Hoc Network (MANETs). The insecurity of the MANETs is because of its mobile essence, high energy consumption and availability of inadequate bandwidth. Due to these uncertainties, it is difficult to establish an efficient and reliable path between the communicating nodes. This leads to instability in route establishment. Thus, there is a need to design an efficient route for transmission between sender and receiver. The best approach is to use multipath routing protocol for route creation between the communicating nodes. The paper presents an approach that chooses the best path from among the available paths between the nodes. To do so, fuzzy cost is the method used in this paper. The proposed approach changes the value of the attributes for a given route with fuzzy cost. A threshold value will be considered initially and the route having a cost more than the initialized threshold would be considered as the best route. This route would be considered as the efficient route for transmission between the sender and the receiver.

In the proposed methodology, instead of using only one metric that is hop count which was used in the previous algorithms, this method considers other parameters as well for calculating the fuzzy cost. In the proposed method, we examine the network based on five features for calculating the fuzzy cost of the link. In both the algorithms FLWMR and FLWLAR, fuzzy controller was modeled considering the non-linearity characteristic. In the proposed technique we take into consideration linearity while calculating fuzzy cost.

The use of mobile devices has been increasing rapidly during the past few decades and this has lead to a lot of significance in the area of MANETs. The use of mobile devices recently needs lot of importance in terms of communication. Since MANET is considered to be an ad hoc network because of the nodes mobility. The topology keeps on varying from time to time, this leads to many issues during routing of messages. This unstructured network of MANET is a major problem that needs to be resolved for the effective routing of packets from sender to receiver. There has been a lot of work done by the researchers in solving the challenges faced in MANETs. The major task researched was to find an optimal path that could be used to transmit the packets from the sender to receiver. All techniques have been proposed efficiently, but still there exists a problem in finding an optimal path between the source and destination.

In any network, there would be various paths to traverse from sender node to receiver node. It is necessary to elect the best and optimal path from among the available routes for successful transmission of packets. There is a possibility of route failures in MANETs. If routes fail, there is a necessity to establish a new path again for the transmission of packets. This incurs usage of resources and spending time in establishing a new route. Thus, there is a necessity that we use the various paths for transmitting the packets even on route failure. This mechanism would be more preferable than establishing a new path on detecting a route failure which would reduce the transfer time for a packet. Since every packet transmitted is associated with a time-out period, it is necessary that the packet needs to be transmitted to the destination within the time-out period.

This paper proposes a novel technique for discovering an efficient path from source to destination for transmitting the packets. For implementing this approach, it is necessary to keep track of the availability of the resources. Another factor that needs to be considered is traffic associated with the routes. These two factors; resources and traffic help in establishing an efficient route from sender to receiver. This reduces the amount of load imposed on the traffic and thus reduces congestion and collision. The proposal is to use fuzzy cost [1], [2], [3], [4] associated with a node for selecting an efficient route from sender to receiver. The previous works related to selecting a route was based on neighbor node information for every node. Fuzzy cost approach allots ranks to each node which help in establishing an efficient route for increasing the transmission rate. With this technique we also achieve excellent distribution.

The organization of the paper comprises literature survey followed by explanation of the protocol used. The later part of the paper includes the implementation of the approach followed by comparing the results obtained for the proposal and ends with conclusion.

2 Methodology

There are different protocols designed for establishing a route from the sender to the receiver. There are protocols that decide the route based on the information stored in the nodes and others decide without referring to any such information. Most of the protocols designed for mobile networks make use of the Destination-Sequenced Distance Vector Routing (DSDV) [5]. DSDV algorithm is an improvement of Bellman-Ford algorithm. It is also a table-driven routing scheme designed for mobile ad hoc networks. The main purpose of the algorithm is to deal with the issue related to routing loops that may be formed. All entries in routing table will be associated with a sequence number. These sequence numbers are mostly even if a link is present, otherwise it will be odd. These sequence numbers are generally created by the destination nodes. The node forwarding the packet has to send the next update with this number.

DSDV uses the concept of Bellman-Ford algorithm with a significant improvement. DSDV assigns to every distance entry $d_{ik}(j)$ with sequence number that has its origin as destination node (i). All the nodes in the network have to maintain the information about this sequence number. Every node needs to increase the sequence number and inform about the updated number to all its neighbors. The two major issues resolved for DSDV are preventing from loops being formed and count-to-infinity. The approach mentioned is very simple to implement. However, the problem with this approach is with the maintenance of the routing tables. This has an impact on the usage of memory for maintaining the tables. This approach also affects the bandwidth usage because every node has to update the routing table information periodically.

On-Demand algorithms are another type of protocols. These algorithms are different from the protocols discussed above. They basically do not need any routing table information being stored by the nodes. DSR (Dynamic Source Routing) [5] is considered to be best routing protocol for On-Demand algorithms. In this approach, the path is establishing only when a node receives a Route Request from another node. Thus, maintaining routing table information is not essential in this technique. This approach was proposed by Broach et al. Perkins et al. proposed another method AODV (Ad hoc On-Demand Distance Vector) routing [6], [5], [7]. This approach produced better results than DSR in terms of establishing a routing path from one to another which is more reliable. This approach reduced the probability of routes being blocked in due course of time. The main part of this method is that it chooses the most direct route or shortest route from all the possible routes between the sender and the receiver.

During the survey, only few papers related to fuzzy logic were found related to the routing algorithm for MANETs. Two routing algorithms were observed on fuzzy logic (1) FLWMR and (2) FLWLAR. Fuzzy Logic Wireless Multipath Routing algorithm only examines the hop count for establishing a route. The algorithm Fuzzy Logic Load Aware Multipath routing also examines traffic load as the parameter assigned to a link for establishing a route. This information is given as input to fuzzy controller. The fuzzy cost is determined depending on the metrics given to the fuzzy controller. This is the procedure used most of the algorithms designed for calculating the cost of the link.

In the proposed methodology, instead of using only one metric that is hop count which was used in the previous algorithms, this method considers other parameters as well for calculating the fuzzy cost. In the proposed method, we examine the network based on five features for calculating the fuzzy cost of the link. In both the algorithms FLWMR and FLWLAR, fuzzy controller was modeled considering the non-linearity characteristic. In the proposed technique we take into consideration linearity while calculating fuzzy cost.

The drawback with approaches which use uni-path for establishing a route from sender to receiver like Destination-Sequenced Distance Vector, Ad hoc On-Demand Distance Vector and Dynamic Source Routing, all utilize the same path again and again for transmitting packets. This leads to excessive use of the resources and leads to overloading for the node. The problem with this approach is that on the failure of an intermediate node, unnecessary RREQ packets are retransmitted because of the design implemented in the routing protocols. These retransmissions of the packets lead to redundancy in broadcasting. In order to deal with this problem, the proposal in this paper is to make use of multipath protocols for routing packets. However, the proposal does consider the load associated with a route, owing to the fact that the traffic load cannot be redirected to multiple paths. The concept used in protocol ImMRMR is that traffic load is allocated effectively amidst the paths that are considered to be best. The best paths are picked based upon the available multiple paths from the sender to the receiver. The criterion used for selecting each best path depends on the various limitations. The five parameters that need to be considered are bandwidth, energy consumption, efficiency, traffic load and hop count.

Table 1. Allocation of resources

Node	Bandwidth (in bps)	Efficiency in Computation	Energy Consumption	Traffic Load	Hop Count
1	60	400	50	0	4
2	40	350	40	3	3
3	30	200	55	2	1
4	20	450	70	1	2
5	70	100	60	4	5

Table 2. Allocation of resources after calculating the cost of node

Node	Bandwidth (in bps)	Efficiency in Computation	Energy Consumption	Traffic Load	Number of Intermediate Nodes	Overall Cost
1	0.848	0.888	0.28	1	0	3.018
2	0.573	0.777	0.42	0.25	0.5	2.518
3	0.485	0.444	0.21	0.5	1	2.574
4	0.279	1	0	0.75	0.77	2.8
5	1	0.222	0.14	0	0.116	1.528

Depending on resources available, ImRMR approach assesses the rank to be assigned from all the available paths from source to destination node. This approach assigns rank to all current paths. However, in the proposed method the cost is driven based upon the importance of the path available. The approach also takes into consideration when ranks are assigned same for more than one vector.

2.1 Selection of Multipath Routing based on Fuzzy Cost

Consider that there are n paths available from the sender to the receiver. In the approach proposed for each path, we consider many parameters for calculating the fuzzy cost. The parameters considered encompasses bandwidth, energy consumption, efficiency, traffic load and hop count. The problem with rank vector technique is that since each node uses the same parameters for assigns the ranks, it would be difficult to identify an appropriate route. This is because there are routes that are assigned with same ranks. This approach creates uncertainty in selecting the best route for forwarding the packets from sender to receiver. The approach used in our proposal assigns an exclusive fuzzy cost for every path. This approach uses the concept of linearity which is missing the previous approaches designed. The past approaches used non-linearity technique.

Let vertices be represented by W and edges be represented by E for any of the adjacent nodes. The edge E can be represented for any two nodes by the equation

$$E_{ij} = E(i,j) = \begin{cases} 0 \\ 1 \end{cases}$$

Let n be defined as the total count of the routes lying between the sender and receiver. In ImRMR, the group of routes is depicted by the equation

$$\prod = \{W_1, W_2, W_3, \ldots, W_n\}$$

where, W_i isthe i[th] vector that is available between sender and receiver. Assume W_s and W_d are representing the sender and receiver nodes. The route from W_s and W_d are depicted by 1.

$$W(W_s, W_d) = W_{i,\ j=1}^{i,j=n} = E(W_s, W_i)\ \ E\ (W_i, W_j)\ \ E\ (W_j, W_d)$$

2.2 Definition of Ranks

Ranks are assigned depending on the values of the metric based on its performance. In this process the ranks depend on the samples provided and are basically sampled on the performance of the system depending on the various metrics considered for providing ranking. The main purpose of ranks being assigned is to decrease the complicatedness that could arise in the process. Thus, high ranks are assigned when minimal values are received for the observations and low ranks are assigned when utmost values are obtained for the observations. The utmost values obtained are given Rank 1. However, the process of assigning ranks is said to fail when we receive similar values for an observation.

Thus, this work proposes the novel approach of using fuzzy cost assigned for each node that involves itself in accomplishing the task of transferring packets from the sender to receiver.

2.3 Implementing Fuzzy Approach in Wireless Ad hoc Networks

The concept of fuzzy sets was initiated by Zadeh. He introduced the concept of membership functions. The fuzzy set is obtained from the generalized form of classical sets based on an indicator function. In order to validate the values fuzzy logic is used. Fuzzy logic validates the accuracy of the truth. There is a difference between the terms probability and degree of truth. They are entirely different terms. The sets are constituted with the fuzzy truth members.

Let us consider X to be any set where membership function X can be defined as a function that can range from X to any interval [0, 1]. The fuzzy subset is expressed based on the membership function X. mA is used to indicate a set of membership function. Any element x that is in X, and then we represent in fuzzy set the membership degree with mA(x) for x. The value mA(x) gives the measure of membership category for x element in fuzzy set. When the value of mA(x) is 0, it indicates x is not in the fuzzy set. When the value of mA(x) is 1, it indicates that x is a part of the fuzzy set. If the value of mA(x) lies in between 0 and 1, then it indicates that x is a part of the fuzzy set partially.

2.4 Fuzzyfication

The attributes stated in Tables 1 and 2 are considered for transforming the attributes of nodes into an equivalent fuzzy measure. The resources in the network are applied with a fuzzy measure function m for calculating the fuzzy cost. This fuzzy measure compares the values of the resources in the interval 0 to 1. This is done for finding out whether the resource is beneficial or not for establishing a route from sender to receiver. The cost (C_i) for a resource (M_i) is evaluated using m (fuzzy measure). In most of the research papers, the process of calculating fuzzy cost of a resource is referred as fuzzyfication.

2.5 Calculating the fuzzy cost

Let us consider that the resource vector M_i having resources ($\lambda_1^i, \lambda_2^i, \lambda_3^i, \ldots, \lambda_k^i$). Let the total number of available resources be k. Let us also consider that from all the resources some are considered to be favorable resources that can establish an efficient route, while some are not favorable resources. For example, we can consider favorable resource as the available bandwidth and non-favorable resources are like traffic load. There are many metrics that can be considered for achieving the objectives and attain an efficient cost metric (C) for the appropriate route to be selected. Some of the metrics that can be considered include available bandwidth, energy consumption, and efficiency in computing; traffic load and number of intermediate nodes (hop count).

In our protocol C is considered to be a linear function. The cost metric C is defined by the equation

$$C = f(BD, N, TL, PC)$$

The bandwidth function is expressed as

$$BD_F^i = BD_T^i - \left(BD_U^i + BD_M^x\right)$$

In our protocol, the mobile gadget is permitted to maintain at a minimum bandwidth BD_F. The remaining bandwidth is permitted to be consumed for establishing other route with its necessary B_M bandwidth. This helps the node to connect with another path which serves at that moment as intermediate node. This means that the total bandwidth of the mobile is not used, but only the required bandwidth of BD_F is used. The remaining bandwidth of the mobile device is left unused while the process of determining a route.

The efficiency in computation is evaluated using the equation

$$E_I = \left(\frac{1}{n}\right) \sum_{x=1}^{n} T_1^{(x)} = \left(\frac{1}{1}\right) \sum_{x=1}^{n} S_M^{(x)} \; / \; C_1$$

Let us consider d as the range in the middle of the two nodes (sender and receiver). The equation for estimating the power of signal is given by

$$P_r\,(d) = \left(P_t G_t G_r{}^2\right) / \left(4 \prod^2\right) d^2\, L$$

Where, the power obtained by sender is denoted by $P_r\,(d)$, the transmitting power is denoted by P_t, the gain obtained in transmitter antenna is denoted by G_t and the gain obtained by receiver antenna G_r.

Table 3. The resource values assigned to nodes of a path

Node	Bandwidth (in bps)	Efficiency in Computation	Energy Consumption	Traffic Load	Number of Intermediate Nodes	Overall Cost
1	60	400	50	1	4	3.018
2	40	350	40	0.25	3	2.518
3	30	200	55	0.5	1	2.574
4	20	450	70	0.75	2	2.8
6	70	100	60	0	5	1.528

2.6 Fuzzy Controller

The fuzzy controller used in our approach considers a total of five inputs. The fuzzy cost is evaluated by the fuzzy controller using the equations mentioned below. These equations are based on the linearity property and are used for calculating the cost. The most important task in the algorithm used for calculating the fuzzy cost is with the fuzzy controller. The algorithm is basically constructed using linear equations. Two classifications have been defined for the linear equations are either favorable or non-favorable.

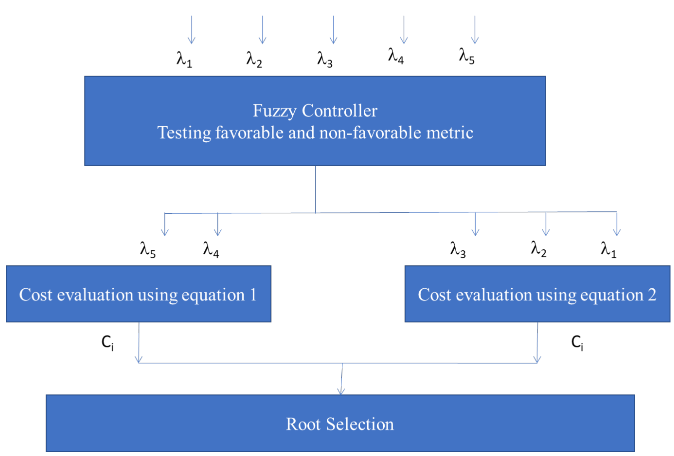

Fig 1. Fuzzy Controller

Consider that favorable is defined by λ_p^i. Then

$$C_i^p = \mu\ \left(v_i\left(M_i\left(\lambda_p\right)\right)\right) = v_i\ \left(M_i\left(\lambda_p\right)\right) / \, max\ \left\{v_i\left(M_i\left(\lambda_p\right)\right)\right\} \tag{1}$$

Also consider that non-favorable is defined by λ_q^i

$$C_i^p = \mu \left(v_i\left(M_i\left(\lambda_p\right)\right)\right) = 1 - v_i\left(M_i\left(\lambda_p\right)\right) / \max\left\{v_i\left(M_i\left(\lambda_p\right)\right)\right\} \quad (2)$$

2.7 Evaluating Fuzzy Cost considering Multipath Routing

Let the input be defined by considering the parameters with vector resources (M) and their corresponding vector paths (V). Let the resources be represented as $(M_1, M_2, M_3, \ldots\ldots, M_n)$ and their vector paths be represented as $(V_1, V_2, V_3, \ldots\ldots, V_n)$.

Let the output be redefined for the vector resources as$(M_{c1}, M_{c2}, M_{c3}, \ldots\ldots, M_{cmax})$. Let us consider that all M_i are designated by a fitness value represented by$(V_{c1}, V_{c2}, V_{c3}, \ldots\ldots, V_{cmax})$.

Algorithm for the proposed approach

∀ i from 1 to n
∀ p from 1 to max resources(k)
if p is found to be favorable
then
$C_i^p = V_i\left(M_i\left(\lambda_p\right)\right)/max\left\{V_i\left(\lambda_p\right)\right\}$
else
$C_i^p = 1 - V_i\left(M_i\left(\lambda_p\right)\right)/max\left\{V_i\left(\lambda_p\right)\right\}$
∀ i from 1 to n
∀ p from 1 to k
cost = $C_i^p + cost$
cost[i] = cost

Every vector in the network uses the above algorithm for designating it with a fuzzy cost. Every path in the network will be designated with a predefined threshold value. The fuzzy cost evaluated with the algorithm will be compared with the threshold value assigned for every vector. The path that has a greater fuzzy cost when compared to the predefined threshold value for each path is opted. This path will be used for transmission of data from the sender to the receiver.

Let us assume that the receiver receives a total of five messages from the sender. This implies that there exist five paths from the sender to receiver. Every node in the network will maintain a vector index with it holding the information about the path. The vector indices for the five paths assumed would contain the following data (60, 400, 50, 0, 4), (40, 350, 40, 3, 3), (30, 200, 55, 2, 1), (20, 450, 70, 1, 2) and (70, 100, 60, 4, 5). The values are taken from Table 1 and represent the parameters' bandwidth, efficiency in computation, energy consumption, traffic load, hop count respectively.

Each of the values representing various parameters is considered based on their importance. The bandwidth value accounts for the bandwidth that the path can sustain. The value for efficiency in computing is based upon the performance of computation that the network could support. The value designated for traffic load defines the utmost number of paths making use of the route and all the intermediate nodes that are visited for an assigned node. The proposed approach prefers considering higher values of bandwidth along with higher values of computing efficiency. The approach also prefers considering lower traffic load along with less consumption of power. The approach also desires that total number of intermediate nodes traversed should be less. The Equations (1) and (2) are applied for calculating the fuzzy cost of the node.

The values shown in Table 2 represent the values assigned to each node is allocated a fuzzy cost of the node. Table 3 depicts fuzzy cost assigned to each node. The routing protocols normally consider the number of intermediate nodes the packet has traversed for taking a decision on which route to consider. Dynamic Source Routing (DSR) and Ad hoc On Demand Distance Vector routing are such protocols. The proposed approach rather considers the predefined fuzzy cost associated with each node. These predefined threshold values assigned are dependent on how many paths are required for transmission.

3 Results and Discussion

3.1 Simulation Parameters

The protocol proposed is executed considering the routing protocol On-Demand Multicast Routing Protocol (ODMRP). The fuzzy cost approach stated in the paper is implemented on ODMRP routing protocol. The protocol has been simulated using Glomosim 2.03. Glomosim library provides an environment simulation for ad hoc or wireless networks. The simulation uses the provision PARSEC for performing parallel simulation. The parameters used for simulation are described in the following statements. The protocol is implemented for a network topology consisting of 30 nodes. These nodes are located arbitrarily at a distance of 2500 meters by 2000 meters. The propagation area of radio varies from time to time. The network bandwidth capacity was considered to be 2 Mbits/second. Throughout the simulation of the protocol no partitions are considered for network. The simulation time for each execution is considered to be 600 seconds.

3.2 Simulation Results

The results of the proposed approach are compared with ODMRP. The comparison was performed considering the performance parameters like throughput, radio collisions, radio ranges, energy consumption and total number of queries. All these performance parameters were compared considering with fuzzy cost and without fuzzy cost.

Figures 2, 3, 4 and 5 depicts throughput with differing node speeds at differing radio ranges. The simulation for throughput is performed with respect to node speed and node mobility considering differing radio ranges. The results exhibit that the performance of throughput is more when executed with ODMRP considering fuzzy cost than when ODMRP is simulated without fuzzy cost. The throughput is increased by 30% when simulated considering fuzzy cost than without fuzzy cost. The simulation is done by taking into account different radio ranges and in each of the cases the performance of throughput is more by approximately 30%. This indicates that the proposed approach for selecting a multi-path route in MANETs using fuzzy cost is better than without considering fuzzy cost.

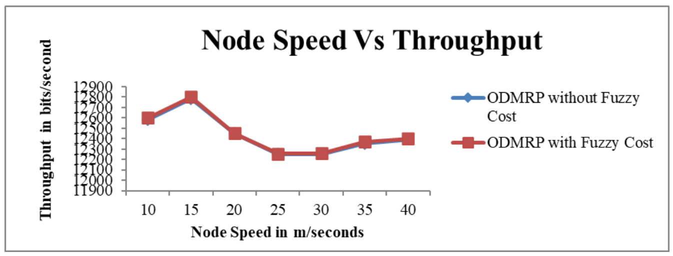

Fig 2. Throughput obtained due to node mobility with radio range of 285m

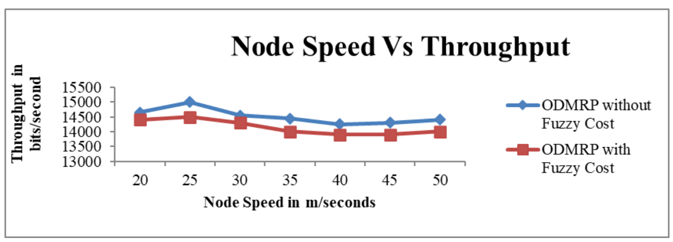

Fig 3. Throughput obtained due to node mobility with radio range of 375m

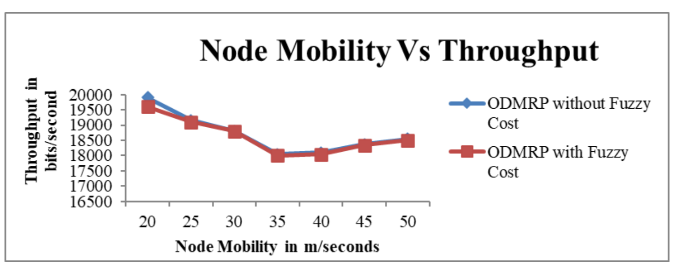

Fig 4. Throughput obtained due to node mobility with radio range of 500m

Figures 6, 7, 8 and 9 depict radio collisions with differing node speeds at differing radio ranges. The simulation resulted that the overall radio collisions is reduced by 35% when simulated with ODMRP considering fuzzy cost than when simulated without fuzzy cost. The simulation was performed considering different radio ranges and in each case there was an approximate reduction in collisions by 35%. The results show that in the proposed approach for selecting a multi-path route in MANETs using fuzzy cost is better than without considering fuzzy cost.

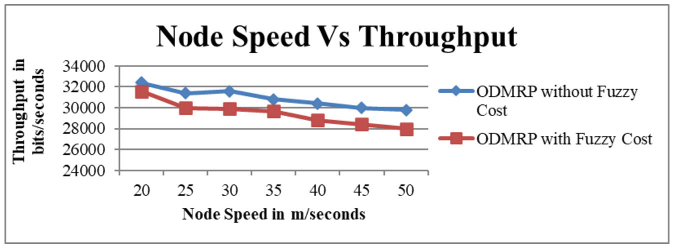

Fig 5. Throughput obtained due to node speed with radio range of 675m

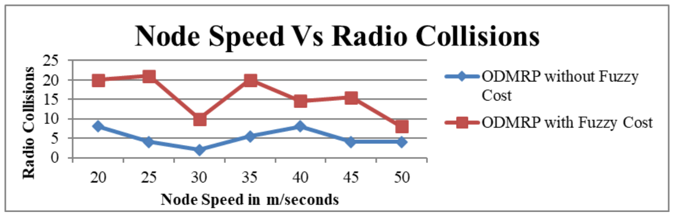

Fig 6. Radio collisions with differing node speeds at radio range of 285m

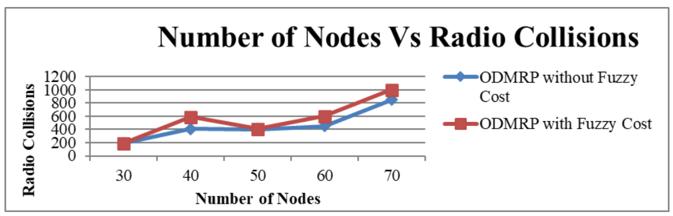

Fig 7. Radio collisions with differing node speeds at radio range of 375m

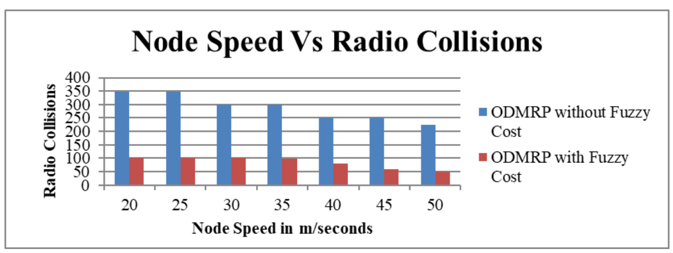

Fig 8. Radio collisions with differing node speeds at radio range of 500m

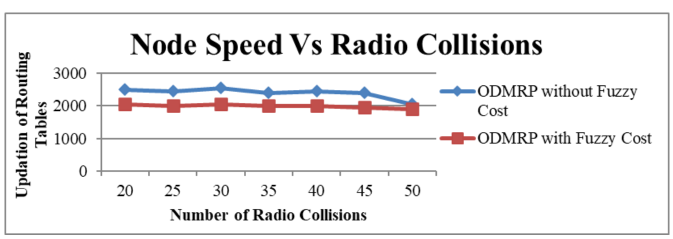

Fig 9. Radio collisions with differing node speeds at radio range of 675m

The simulation results considering energy consumption are depicted in Figures 10, 11, 12 and 13 on ODMRP. The simulation exhibited that energy consumption is reduced by 5% when simulated with ODMRP considering fuzzy cost rather than when simulated without fuzzy cost. The simulation was performed considering different radio ranges and in each case, there was an approximate reduction in energy consumption by 5%. The results show that in the proposed approach for selecting a multi-path route in MANETs using fuzzy cost is better than without considering fuzzy cost.

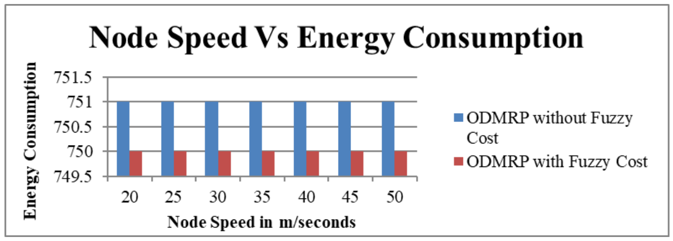

Fig 10. Energy Consumption with differing node speeds at radio range of 285m

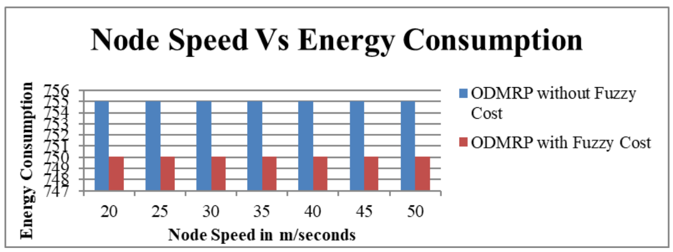

Fig 11. Energy Consumption with differing node speeds at radio range of 375m

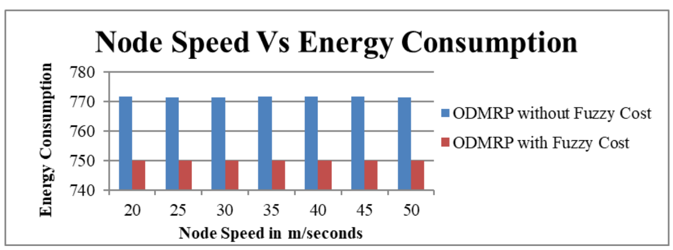

Fig 12. Energy Consumption with differing node speeds at radio range of 500m

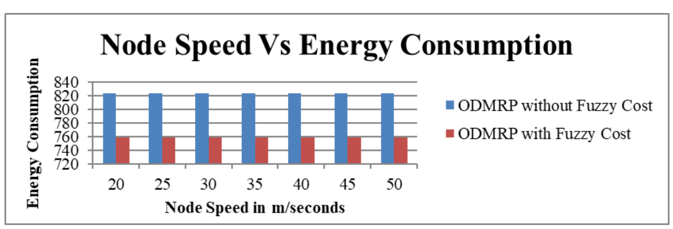

Fig 13. Energy Consumption with differing node speeds at radio range of 675m

The simulation results with differing node speeds and differing radio ranges for total queries is depicted in Figures 14, 15, 16 and 17. It results exhibit that there is a fall in the queries count with an increase in the radio range between the nodes. While considering fuzzy cost it is observed that there is a fall in the queries count by approximately 23%. The total queries executed are decreased when simulated with ODMRP considering fuzzy cost.

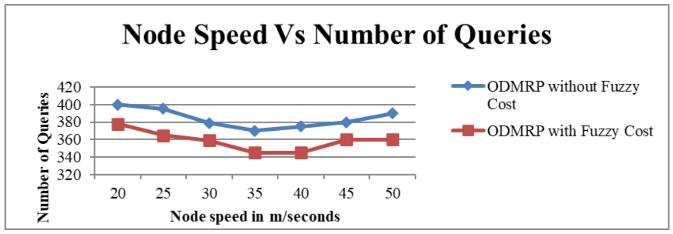

Fig 14. Number of Queries with differing node speeds at radio range of 285m

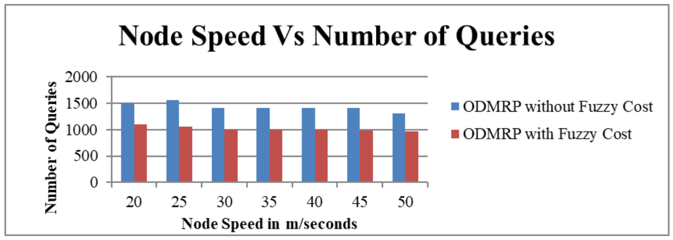

Fig 15. Number of Queries with differing node speeds at radio range of 375m

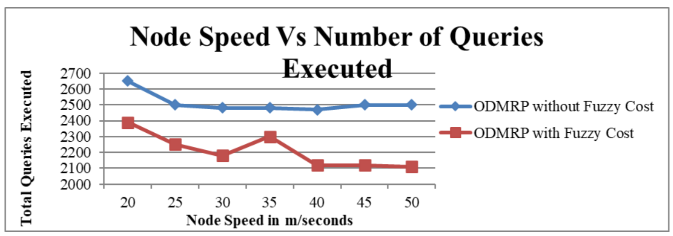

Fig 16. Number of Queries with differing node speeds at radio range of 500m

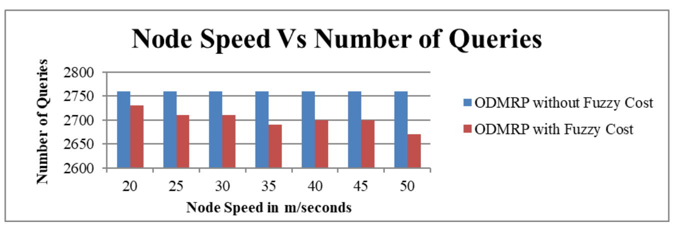

Fig 17. Number of Queries with differing node speeds at radio range of 675m

4 Conclusion

In any network, the performance of the network is based on the QoS provided. Till date, multipath protocols are effective and reliable protocols that are in existence. Many factors are considered by multipath routing protocols like presence of two or more paths based upon the load is beneficial for multipath routing. Due to the benefits that could be achieved through multipath routing, fuzzy cost approach is proposed in this paper. This paper proposes a novel technique for discovering an efficient path between communicating nodes for transmitting the packets. For implementing this approach, it is necessary to keep track of the availability of the resources. Another factor that needs to be considered is traffic associated with the routes. These two factors; resources and traffic help in establishing an efficient route from sender to receiver. This reduces the amount of load imposed on the traffic and thus reduces congestion and collision. The proposal is to use fuzzy cost associated with a node for selecting an efficient route from sender to receiver. The previous works related to selecting a route was based on neighbor node information for every node. Fuzzy cost approach allots ranks to each node which help in establishing an efficient route for increasing the transmission rate. With this technique we also achieve excellent distribution.

This study establishes an efficient path from among all the paths available for transmitting the packets. The proposed method discovers fuzzy cost for each node and based upon the ranks assigned for each node decides or selects an efficient and effective path from the sender to receiver for establishing an efficient route. The proposed mechanism with inclusion of fuzzy cost shows 5% energy efficiency, reduces the collisions by about 35% and throughput is enhanced by 30%. There has been a considerable decrease in the number of queries by 23%. This approach is considered to be more useful and significant while considering fuzzy cost as a means for an effective route.

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