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ENERGY EFFICIENT CLUSTERING USING PSO AND FUZZY LOGIC FOR HYBRID MANETs

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ABSTRACT

In MANETs, development of an energy efficient routing protocol is essential. The cost of the network depends on the energy consumption of each mobile node. Overutilization of energy by a mobile node cannot contribute to the utility of the network as a whole. In order to optimize the utilization of energy at each node, we propose an Energy Efficient Clustering using PSO and Fuzzy logic for Hybrid MANETs (EC-PFHM). It can minimize the energy consumption and increases the network lifetime. In our proposed approach, an energy efficient cluster head selection is performed using particle swarm optimization (PSO), where the nodes with high residual energy and connectivity are elected as cluster head (CH). Appropriate super cluster head (SCH) is selected by using fuzzy logic. By this the overall networks overhead is reduced and hence the QoS of the network is enhanced. The result obtained through NS-2 simulation shows that the proposed algorithm performs better than FQ-MP-OLSR and BPSO-TORA approaches in terms of reduced energy consumption, delay and increased throughput.

Keywords: mobile ad hoc network (MANET), multipath routing, clustering, cluster head (CH), super cluster head (SCH), particle swarm optimization (PSO), quality of service (QoS), network simulator2 (NS-2).

1. INTRODUCTION

1.1 MANET

Mobile ad hoc networks are necessary when infrastructure does not exist or is difficult to set up. They are appropriate in disaster recovery, search and rescue in remote areas, battle fields, patient monitoring, Bluetooth, sensors, cyclone evolution analysis, detection of earth quakes, interactive museums or toys, providing security at public buildings, and locating an object. Mobile ad hoc networks facilitate users to communicate without any physical infrastructure. The construction of temporary network with no wires, no communication infrastructure, and no administrative intervention is required. Every node acts as a router and host to forward the data packets in MANETs. The nodes can move randomly. In a large scale of networking environment, one of the most important networking factors is self-organising capability for well adaptation of dynamic situations and interoperating capability between the nodes.

Efficiency of wireless links are always much lower than wired counterparts. Almost, while several are available for different Gbps, wired LAN, this time, especially around 2 Mbps commercial applications for wireless LANs. Secondly, the device battery power, which is limited in time, does not allow infinitive action for that node. Moreover, the battery provides power for all the equipment, which does not allow nodes to the ordinary operation is limited in time. Due to the limitations of power, transmission range and node mobility, path failures are very frequent in this type of network. To accommodate frequent path failures, special routing protocols are necessary.

1.2 Hybrid MANET

A Hybrid wireless network is the combination of a mobile ad hoc network and an infrastructure network. Hybrid MANET is imparted by the gateways (GWs) connecting the MANET with the internet which also gives advanced communication, network scalability, and pervasive sustainable environments. Studies related to GW management, mobility management, addressing, and routing are undergone in the hybrid MANETs. Additionally, logical and technological developments are needed for robust interconnection. With the fixed IGWs the hybrid MANET provides internet access to the MANET nodes. It also exploits mobility capability of additional mobile nodes (mobile IGWs). The benefits of the proactive and reactive approaches are also balanced by the hybrid approach. The dynamic network topology leads to uncertainty in the connectivity of the mobile nodes with gateway nodes and mobile nodes with other active mobile nodes. In the local MANET, there is a delay in finding route to destination due to the mobility of mobile nodes. [4].

Hybrid discovery gateway combines the best of both proactive and reactive approaches. All the mobile nodes in a certain range (which is decided by a limited number of hops which is called as TTL) around a gateway use the proactive gateway discovery scheme while the mobile node residing outside that range use reactive gateway discovery to communicate with gateway. [5].

1.3 QoS Improvement on Multimedia

The QoS requirements are set and these applications help in reducing the node mobility. The streaming video in the WMSN causes the data harvested from the target to be more complex. There are possibilities

of rigorous constraints due to visual data. Few operations like Collection, processing, and dissemination of visual data causes demands in bandwidth and the processing. The images, video, audio and scalar data present in the multimedia data have different metrics. It is necessary to promote high data rate accommodation in order to design an efficient routing protocol. For a feasible WMSN deployment, the efficient routing of data packets from sensors to base station is quite important as concerned to data centered networks. During the query and data dissemination phases, optimal routing is a vital role since the multimedia content is conditional to strict QoS requirements. In addition to the end to end delay, QoS based routing also considers the jitter, throughput as its main objective for path selection. The routing decisions do not consider the energy metric in the routing algorithms [23].

However, WMSN applications require certain performance guarantees such as end-to-end delay, jitter, minimum Bandwidth etc. For instance, transmission of imaging data in a disaster management setup requires careful handling in order to ensure that the end-to-end delay is within acceptable range and the images are received properly without any distortion. Such time constrained applications have posed various QoS issues in wireless sensor networks. Thus it has become necessary to develop protocols that are QoS based and also able to minimize energy so that network lifetime increases [24].

Our contributions In this paper, we propose energy efficient clustering using PSO and fuzzy logic for Hybrid MANETs (EC-PFHM). In multipath routing energy efficiency is achieved by clustering techniques.

The remainder of the paper is organized as follows. Sections 2 presents the recent works related to our contributions. The problem formation and solution with the system model is describes in Section 3. We propose energy efficient routing protocol details and its mathematical formulation is present in Section 4. The performance of proposed protocol is present in section 5. Finally, the paper concludes in Section 6.

2. RELATED WORKS

2.1 Existing Works on Cluster based Routing

Srinivas Kanakala *et al* [1] have considered the issues of energy efficient communication in MANETs using network coding. Network coding is an effective method to improve the performance of wireless networks. COPE protocol implements network coding concept to reduce number of transmissions by mixing the packets at intermediate nodes. They incorporated COPE into cluster based routing protocol to further reduce the energy consumption. The proposed energy-efficient coding-aware cluster based routing protocol (ECCRP) scheme applies network coding at cluster heads to reduce number of transmissions. They also modified the queue management procedure of COPE protocol to further improve coding opportunities. They also used an energy efficient scheme while selecting the cluster head. It helps to increase the life time of the network.

Karamjeet Kaur *et al* [2] have virtually divided the network into regions according to the proximity to the BS denoting the closest region as the front region and the farthest region as the rear region. The nodes have been classified according to the region that they fall in. Based on their model, transmission tuning algorithm for cluster-based WSNs has been proposed to balance the load among cluster heads that fall in different regions. This algorithm is applied prior to a cluster algorithm to improve the performance of the clustering algorithm without affection the performance of individual sensor nodes.

Aruna *et al* [3] have introduced a new cluster-head election scheme to reform the cluster. This scheme is based on providing an alternative clusterhead (SCH) for each primary clusterhead (PCH). This SCH is an ordinary member node, which is identified and elected by its PCH to be the future leader of the cluster. When the PCH is no longer being a cluster head, the SCH will be triggered to be the PCH, by the former PCH. Since the SCH is known by all member nodes, the cluster leadership is transferred efficiently without affecting the performance of the network. Also, their proposed protocol (SD-CBRP) aims at improving quality of service with security.

2.2 Existing Works on Multipath Routing

Sung wook Kim et al [6] have proposed a new multipath routing scheme by employing simulated annealing approach. The proposed meta heuristic approach can achieve greater and reciprocal advantages in a hostile dynamic real world network situation. Therefore, the proposed routing scheme is a powerful method for finding an effective solution into the conflict mobile ad hoc network routing problem.

Sajal Sarkar *et al* [7] have proposed a secure and energy-efficient stochastic multipath routing protocol based on a Markov chain for mobile ad-hoc networks (MANETs). The proposed routing protocol computes multiple paths between source-destination pairs and selects an energy-efficient path stochastically from those paths to forward the data packets. In addition, this protocol also secures data flow in the network as the packets are forwarded through random paths from the source node to the destination node. The random data flow paths make it difficult to jam, intercept, and hijack data packets as this will require the attacker to listen to all possible paths from the source to the destination.

May Cho Aye *et al* [8] have proposed an energy efficient multipath routing protocol for choosing energy efficient path. This system also considers transmission power of nodes and residual energy as energy metrics in order to maximize the network lifetime and to reduce energy consumption of mobile nodes. The objective of their proposed system is to find an optimal route based on two energy metrics while choosing a route to transfer data packets.

Prabha *et al* [9] have proposed improvements in AOMDV based on Link Quality. A link estimation algorithm-based AOMDV was proposed (LQ-AOMDV). The proposed LQ-AOMDV was optimized to obtain optimal solutions. A novel objective function was

proposed to balance the load across the network and improve the network performance.

Yujun Zhang *et al* [10] have analyzed the threats of topology-exposure and propose a TOpology-HIding multipath Protocol (TOHIP). TOHIP does not allow packets to carry routing information, so the malicious nodes cannot deduce network topology and launch various attacks based on that. The protocol can also establish multiple node-disjoint routes in a route discovery attempt and exclude unreliable routes before transmitting packets. They formally proved that TOHIP is loop-free and does not expose network topology. Security analysis shows that TOHIP can resist various kinds of attacks efficiently and effectively.

Harold Robinson *et al* [11] have proposed an energy-aware multipath routing scheme based on particle swarm optimization (EMPSO) that uses continuous time recurrent neural network (CTRNN) to solve optimization problems. CTRNN finds the optimal loop-free paths to solve link disjoint paths in a MANET. The CTRNN is used as an optimum path selection technique that produces a set of optimal paths between source and destination. In CTRNN, particle swarm optimization (PSO) method is primly used for training the RNN. The proposed scheme uses the reliability measures such as transmission cost, energy factor, and the optimal traffic ratio between source and destination to increase routing performance.

3. ENERGY EFFICIENT MULTIPATH ROUTING PROTOCOL

In this section, we first describe the problems of existing protocols in Boushaba *et al.* [18] and Jamali *et al.* [17], and proposed solution for that problem. We then describe the system model for proposed solution.

3.1 Problem Identification

The instability and limited resources in mobile ad hoc networks (MANETs) make the video transmission over such networks a challenging task. Transmission of video streams through multipath routing protocols in MANETs can enhance the quality of video transmission. In [18], authors proposed extension of MP-OLSR (multipath optimized link state routing protocol) [19] [20], named FQ-MP-OLSR (fuzzy based quality of service MP-OLSR).

To schedule multimedia traffic FQ-MP-OLSR uses weighted round-robin (WRR) scheduling algorithm, where the path weights, needed for scheduling, are computed using the multi-constrained QoS metric provided by the first fuzzy system. However, the following limitations are involved in FQ-MP-OLSR. They considered only three QoS links metrics: delay, throughput and signal to interference plus noise ratio (SINR) but for video transmission, energy level, bandwidth need to be considered.

Jamali *et al.* [17] have proposed joint routing protocol called Binary Particle Swarm Optimization using TORA (BPSO-TORA) approach which is more scalable. It enhances the energy effectively by selecting path which has high weight based on energy and distance factors also handles the problems occurred during routing discovery process. Shortest routes will be under heavy load, then nodes energy will be decreased soon. Lifetime of network need to be considered

The research in MANETs with the QoS routing focused on energy consumption. In the establishment of a network in the linked hierarchy, the clustering mechanism forms an efficient topology control methodology which stabilizes the traffic load and improves the overall performance and also increases the lifetime of MANETs. A node wants to send information to another node; it has to select an optimal path such that the obtained QoS should be optimal. The QoS of the received information mainly depends on the available energy, bandwidth, stability of established path and the time delay of the respective path.

But existing works on energy efficient routing are either multipath oriented or hierarchical. There are very few works which integrates both hierarchical and multipath routing concepts. The existing hierarchical or cluster based approaches are based on single cluster head only which deplete the energy levels of cluster heads quickly. Moreover, the bandwidth and connectivity metric should be considered in addition to the residual energy, because of the frequent mobility of nodes in MANET.

In order to solve these problems, in this paper, we propose an energy efficient multi path routing protocol which contains the following main contributions:

a) An efficient clustering is performed using PSO [21], where all the nodes are clustered without any residual nodes left in the system.
b) Using the appropriate selection of cluster head (CH) and super cluster head (SCH) [22] the overall networks overhead and energy consumption are reduced and hence the lifetime of the network is enhanced.
c) Multipath routing is preferable for real time traffic to reduce the time delay improve throughput with reducing energy consumption.
d) The performance of the proposed routing approach is validated using packet loss ratio, energy consumption, routing cost, mobility, delay, and throughput.

3.2 System Model

The system model for our proposed network model is shown in Figure-1. The network consists of base station (BS), mobile nodes (MNs), cluster head nodes (CHs) and super cluster head nodes (SCHs). BS employed to collect the information from the mobile nodes. Every clusters have a CH node, which collect all the information from other nodes in own cluster. The CHs are only eligible to directly communicate with the neighboring CHs node. Then the collective CHs are together to select the best node i.e. SCH from among the CH such that only SCH is eligible to directly communicate with the base station.

The proposed routing protocol consists of three stages such as cluster formation, cluster head selection (CH) and super cluster selection (SCH) and the processes steps are briefly described in the following sub sections.

3.3 Basics of Particle Swarm Optimization

In the proposed protocol PSO is employed for efficient clustering of nodes with least redundant (un-clustered) node in the network. It is a random optimization technique based on population and computational technique that optimizes a problem (situation) using series of iterations to enhance the possible solution for a given quality measure A solution to the problem of complex non-linear optimization has been proposed using PSO. It simulates the behavior of flocking birds, where a group of birds randomly search food in a given area. Consider there is only one piece of food in the area of search and no birds know the where the food is. But they know how far the food is in each iteration. Hence, the best strategy is to follow the bird which is nearest to the food.

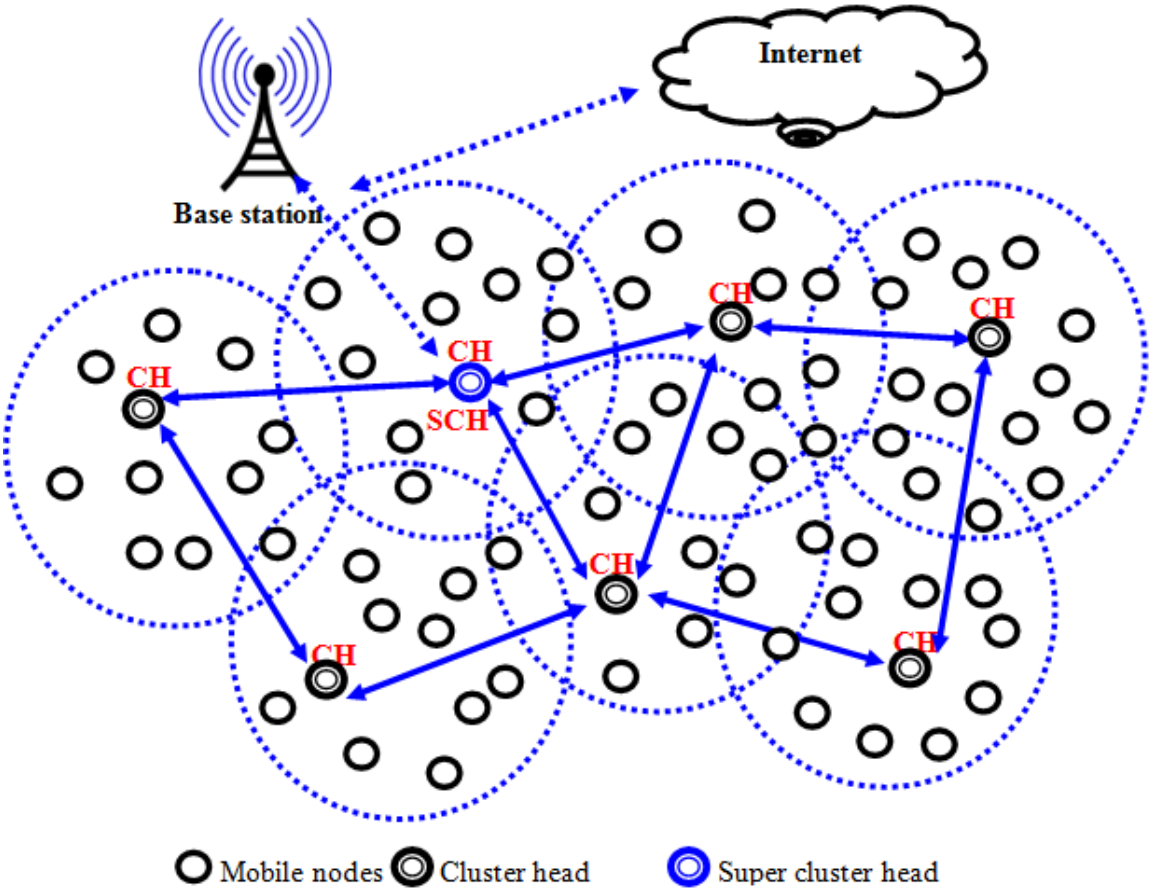


Figure-1. System model for Hybrid MANET.

3.3.1 Clustering using PSO

Initially, when all the nodes are deployed in the network, the mobile nodes communicate with every other node in the given region, by broadcasting an HELLO_message, in their cluster region. The HELLO message format is shown in Table-1.

Table-1. Hello message format.

Hello Message			
Node's ID	Residual energy	Band width	Connectivity

In this proposed algorithm, each node is considered as the particle. Here the base station makes the nodes to perform cluster formation, which is carried out using PSO.

Using PSO, the fitness of each particle is calculated to choose the cluster head.

Fitness value is estimated based on the following metrics:

- The residual energy of the node (RE_{avg})
- Connectivity (C_n)

The nodes with maximum number of connectivity and residual energy are considered as the cluster head.

$$F = K_1.RE_{avg} + K_2.C_n \quad (1)$$

K_1 and K_2 are weighing factors.

Fitness value of each node is calculated during every iteration and the maximum fitness value obtained is taken as the local_best. The maximum value among all the fitness values obtained is taken as global_best. Maximum fitness valued node is considered as cluster head.

3.3.2 SCH Selection using fuzzy logic

- The SCH is selected among the existing CH's using fuzzy interface engine by choosing fuzzy inputs such as Available Band Width (ABW), Residual Energy (RE) and Mobility (M).
- SCH is selected based on fuzzy output i.e. $SCH_{eligibility}$

Fuzzy Logic System (FLS): This system is used for logical reasoning with an approximation-based approach as disparate to an exact solution. Due to the fuzziness, it provides solutions within the range between 0 and 1 (not exactly 0 or 1). The Block diagram of Fuzzy Logic System is shown in Figure-2.

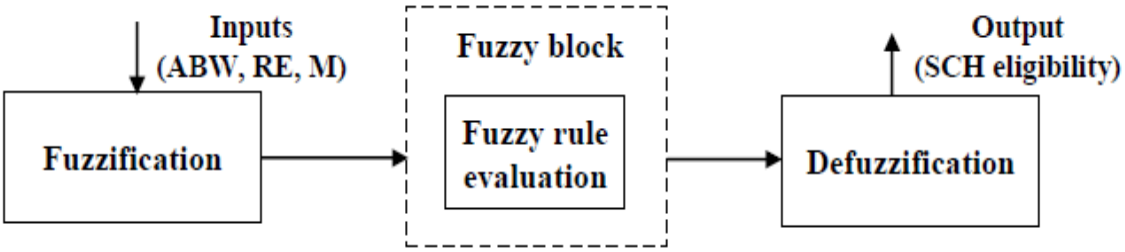


Figure-2. Block diagram of fuzzy logic system.

The linguistic variables for the fuzzy set are set low, medium and high. Both trapezoidal and triangular membership functions are employed for less, high and medium variables respectively. The fuzzy rules are driven by fuzzy input sets such as ABW, RE and M.

Fuzzification: It is the process of transforming the inputs (i.e., Available Bandwidth, Residual Energy and Mobility) to a numerical format. The output is normalized into fuzzy set (0 to 1). At this moment, the input is mapped to govern the crossing points of every function. Depends on our assessment, triangular (low, medium, and high for output) and trapezoidal (low, medium, and high for the three inputs) functions are applied. An example of a membership function for the given inputs such as Available Bandwidth, Residual Energy and Mobility is shown in Figure-3.

Fuzzy rule: It depends upon the membership function i.e. if/then rule and used to produce the input-to-output mapping.

Fuzzy rule evaluation: The fuzzified inputs are taken and applied to the antecedents of the Fuzzy rules. It is then applied to the consequent membership function. By using an aggregation method, Fuzzy inference engine generates the output for the given inputs. This method is referred as the intersection operation.

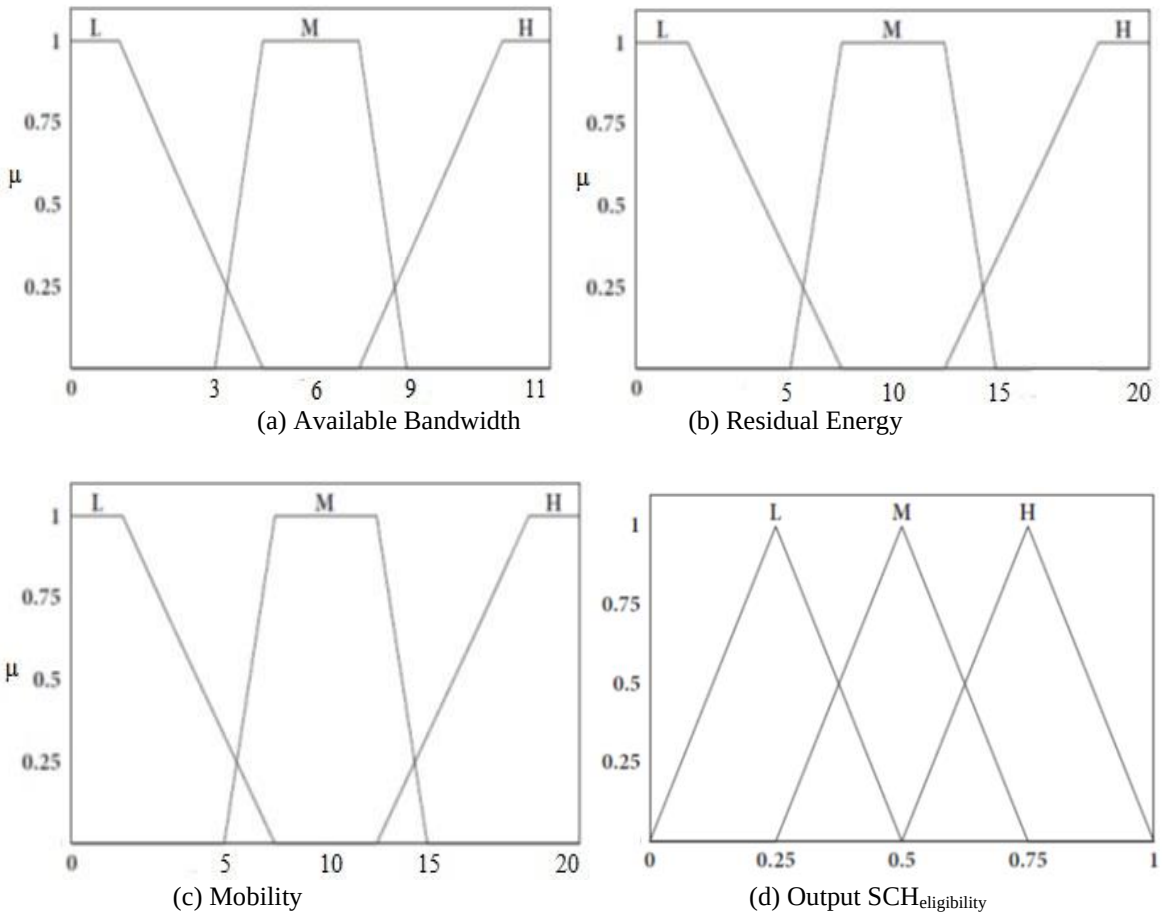
Defuzzification: It is a process of transforming the fuzzy output variable into the crisp output.

Membership function: The membership function is used to define the crisp input into fuzzy inputs. In our case, the crisp inputs Available Band Width, Residual Energy and Mobility are described by the fuzzy inputs in terms of three levels such as low (L), medium (M) and high (H). The membership functions of all inputs and corresponding output i.e. $SCH_{eligibility}$ are depicted in Figure-3.

Membership function for fuzzy set on X is defined as μ: X→ [0,1], where each element of X is mapped to a value between 0 and 1, called as degree of membership.

X is input value (ABW, RE, M)

Input is represented by trapezoidal function and output ($SCH_{eligibility}$) by a triangular function.



(a) Available Bandwidth (b) Residual Energy

(c) Mobility (d) Output $SCH_{eligibility}$

Figure-3. SCH Membership function: Available bandwidth, residual energy, mobility and output $SCH_{eligibility}$.

For 3 inputs (ABW,RE,M) and 3 crisp values (L,M,H), total 27 If/Then rules can be formed.

A CH has a high chance of being an SCH only if any of the conditions is satisfied as shown in Table-2. Hence, using this fuzzy logic the best CH is elected as the SCH, with maximum Available Band Width and Residual Energy, and less Mobility.

Table-2. Fuzzy rules for selection of SCH from multiple CHs.

S.No.	ABW	RE	M	$SCH_{Eligibility}$
1	H	L	L	M
2	H	L	M	M
3	H	M	L	**H**
4	H	L	H	L
5	H	H	L	**H**
6	H	H	M	M
7	H	M	H	M
8	H	H	H	M
9	H	M	M	M
10	M	L	L	M
11	M	L	M	**L**
12	M	M	L	M
13	M	L	H	L
14	M	H	L	M
15	M	H	M	M
16	M	M	H	M
17	M	H	H	M
18	M	M	M	M
19	L	L	L	L
20	L	L	M	L
21	L	M	L	M
22	L	L	H	L
23	L	H	L	M
24	L	H	M	M
25	L	M	H	L
26	L	H	H	L
27	L	M	M	L

Finally, in this way SCH node selection leads to minimize the communication overhead, energy consumption and increases network lifetime.

3.3.3 Inter-cluster multipath routing

After selecting the CH and SCH, the data has to be transmitted to the base station or another mobile node. For this, Intra and Inter cluster routing have to be determined. In intra-cluster routing, all the cluster members transmit their data to their CH. In inter-cluster routing, multipath routing is applied in which multiple paths are to be determined between each CH. The following algorithm illustrates the steps involved in inter-cluster multipath routing.

Inter-cluster Multipath Routing Algorithm

Let S and D be the source and destination nodes.

Let CH_S and CH_D be the cluster heads of S and D, respectively.

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1. If S want to transmit data to D, then
2. S sends s REQ to CH_S
3. CH_S forwards REQ to all its neighbor CHs , CH_j
4. Each CH_j includes its id and ABW information into REQ
5. Each CH_j forwards the modified REQ to CH_{j+1}
6. If $CH_{j+1} = CH_D$, then
7. CH_D forwards REQ to D
8. D generates REP
9. D transmits REP to CH_{j+1}
10. CH_{j+1} includes its id and ABW information into RREP
11. CHj+1 forwards modified RREP to CH_{j-1}
12. If $CH_{j-1} = CH_S$, then
13. CH_S forwards RREP to S
14. S receives all RREPs from CH_S
15. S selects the path with Max(ABW)
16. End if
17. End if
18. End if

4. SIMULATION RESULTS

The Network Simulator (NS2) tool is used to simulate the proposed routing protocol EC-PFHM. The Simulation Configuration is given in Table-3. The performance of routing protocol is analyzed by QoS metric analysis.

The proposed EC-PFHM routing protocol is compared with FQ-MP-OLSR and BPSO-TORA routing protocol by considering network parameters such as consumed energy, network lifetime, throughput, delay and drop ratio by varying the node speed.

4.1 Simulation Configuration

Table-3. Simulation Configuration.

Number of Nodes	100
Area Size	1000 X 1000m^2
MAC Protocol	802.11
Transmission Rate	50Kb/s
Propagation Model	Random Way Point
Transmission Range	250 m
Initial Energy	20 Joules
Transmission Power	0.660 watts
Receiving Power	0.395 watts
Bandwidth	11 Mbps
Speed of Mobile	5,10,15,20 and 25m/s

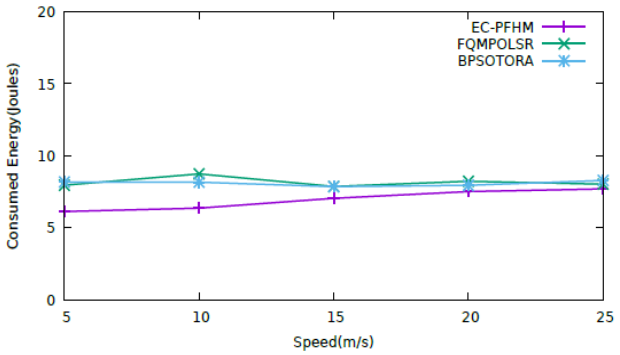

Figure-4. Speed Vs Consumed energy.

As shown in Figure-4, the Consumed energy of EC-PFHM is lower than the existing FQ-MP-OLSR and BPSO-TORA routing protocols with increasing speed.

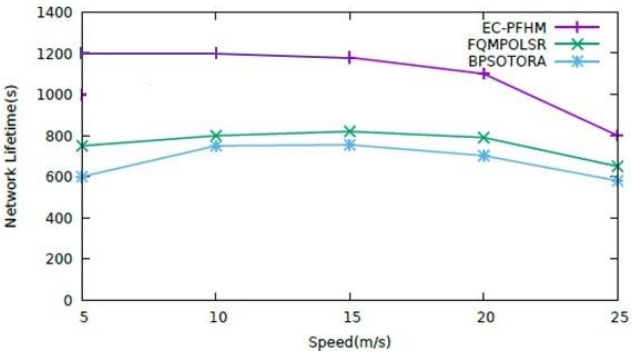

Figure-5. Speed Vs Network lifetime.

Figure-5 depicts the Network Lifetime of EC-PFHM which is better than existing FQ-MP-OLSR and BPSO-TORA routing protocols with increasing speed.

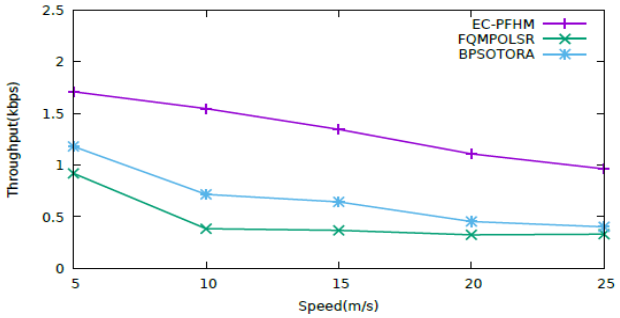

Figure-6. Speed Vs Throughput.

Figure-6 depicts throughput of EC-PFHM which is better than the existing FQ-MP-OLSR and BPSO-TORA routing protocols with increasing speed.

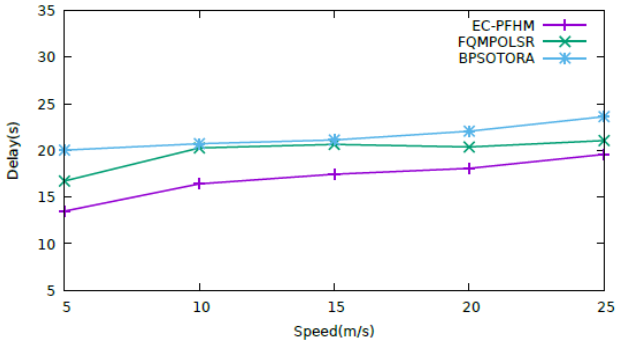

Figure-7. Speed Vs Delay.

As shown in Figure-7, the Delay of EC-PFHM is lower than the existing FQ-MP-OLSR and BPSO-TORA routing protocols with increasing speed.

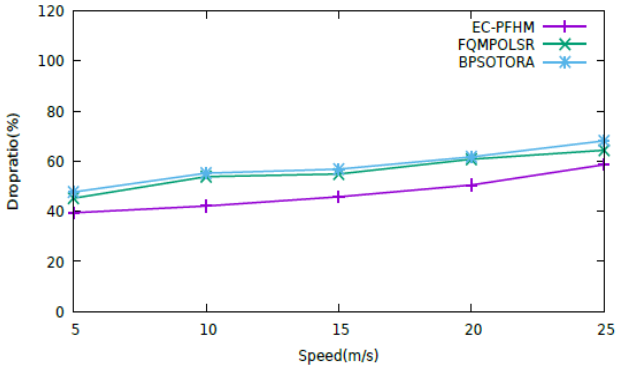

Figure-8. Speed Vs Drop ratio.

As shown in Figure-8, the Drop ratio of EC-PFHM is lower than the existing FQ-MP-OLSR and BPSO-TORA routing protocols with increasing speed.

5. CONCLUSIONS

In this we presented the proposed energy efficient clustering protocol using PSO and Fuzzy logic for Hybrid MANETs (EC-PFHM). It constructs a cluster, elects the CH and SCH. It minimizes communication overhead, energy consumption and increases network lifetime. In the process of routing, multiple paths are generated from source to destination; high bandwidth path is selected for data transfer. The QoS metrics analysis indicates the proposed EC-PFHM maximize the QoS metrics such as Consumed energy, network lifetime, throughput, delay and drop ratio by varying network parameters such as node speed in comparison with FQ-MP-OLSR and BPSO-TORA routing protocols.

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