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A HYBRID OPTIMIZATION APPROACH FOR CLUSTERING AND ROUTING IN MANET

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ABSTRACT

Mobile Ad Hoc network (MANETS) technology is one of the best to create a network on demand. In MANET environment clustering and routing is an important concern to maintain the stability of the network. The additional overheads in MANETs like scalability, reliability, dynamic nature, bandwidth limitation, and heterogeneous device configuration leads to unstable network environment. In MANET, clustering technique is used to form a group of mobile nodes as a network. In the existing clustering techniques, the parameters are initialized with a predefined value and the performance of a clustering algorithm is totally based on this predefined value, which is considered as the major disadvantage of the existing clustering techniques. Unstable clustering leads to serious performance issues like delay, packet drop, and network disconnection. In this paper, we propose combinatorial optimization algorithm for clustering and routing in MANET using ACO, Black Hole (BH), Fuzzy Set (FS) such as BH-ACO, BH-FUZZY, BH-PSO, BH-COA, BH-LSTM, BH-FS-ACO-LSTM. The proposed algorithm focuses on the areas of clustering on MANET. It reduces delay in cluster formation process. It enables the parameters to adapt the values dynamically. From the experimental results it is clear that the proposed approach is able to achieve the best convergence rate and thus may achieve the best performance.

Keywords: ACO, Black Hole (BH), Fuzzy Set (FS), LSTM, MANET, Clustering, Load balancing, Routing.

I. INTRODUCTION

MANET is a collection of independent mobile nodes, grouped without the support of any wired network. The geographical position of the mobile nodes may keep on changing and due to its dynamic nature; the MANET topology changes frequently, also it a self-organized network; it does not involve any central control devices to administrate the nodes in the network. The self-configurable network architecture leads to the automatic connections and disconnection of mobile nodes in the network. The cross-layer design aspects, mobility, and energy consumption issues affect the quality of service (QoS) of MANET [3]. In MANET, each mobile node acts as a router, it routes traffic to destination through the neighbouring mobile nodes. All the mobile nodes discover the neighbouring mobile node and update the information in the routing table, the routing entries are updated automatically. Various routing techniques apply different metrics Routing protocol routes based on the predictions of the future position of the mobile node [2]. MANET is a heterogeneous network environment; here different configurations of mobile nodes are connected together. Due to its dynamic nature and high mobility speed, it is lack on the following areas like availability, integrity and confidentiality. Clustering the MANET environment without reducing the throughput is a challenging task, because it is a more complex network in nature. Various clustering techniques apply different metrics, the potential and stability factors considered in cluster-head election process [1]. A schema to improve the cluster stability and in-turn improves the performance of traditional cluster-based routing protocol (CBRP), by electing secondary cluster head for each cluster, to increase the stability of the cluster in case of sudden failure of cluster head [5]. Bio-inspired algorithms like genetic algorithm (GAs), ant colony optimization (ACO) algorithm, particle swarm optimization (PSO) and many other similar algorithms are applied in many fields for optimizing the complex problems. Artificial Bee Colony Optimization Technique is used to discover route in MANET [6], to provide optimal path and minimize the routing overhead. Black Hole Algorithm is a new bio-inspired metaheuristic approach based on observable fact of black hole phenomena, it is free from parameter tuning issues like, does not suffer from premature convergence problem [7-10]. From previous studies it's understood that the optimization problems are efficiently solved using evolutionary algorithms. Several parameters are involved in the optimization algorithm, like population size and selection rate. The biggest challenge is deciding the values for the parameters used in these algorithms. So, mostly the values are predefined in these algorithms. A cluster-based MANET has many important issues to examine, such as the cluster structure stability, the control overhead of cluster construction and maintenance, the energy consumption of mobile nodes with different cluster-related status, the traffic load distribution in clusters [4].

Heuristics approach is a trial-and-error methodology, which is used to find an approximate optimal solution for the complex problems at low computational cost. The characteristic is based on biological approach and are motivated by nature phenomena. Its main objective is to solve the complex problem more quickly. It is an alternative for the traditional approach, when the traditional approach is too slow or not able to find a solution for a complex problem. The term Metaheuristic was introduced in the research paper. Metaheuristic approach is a high-level methodology, which is used to find a better solution than the heuristic approach. It represents a set of heuristic approach to find the optimal solution for a complex problem. It applies a local search technique and it is basically an iterative based approach, which finds an optimal solution to a complex problem. The search process depends on two major components that are diversification (exploration) and intensification (exploitation). It is a heuristic approach inspired by the theory of natural evolution. It applies the survival of the fittest tactic in the solution space. It represents the nodes in the solution space as string of bits similar to genes and chromosomes. Genetic algorithm initializes the solution space with an initial population of nodes as strings. In each iteration, a set of operators like reproduction, crossover, and mutation are used in the solution space to generate an improved solution. In every iteration, it produces comparatively a better solution than the previous iteration. GA are applied in the wide variety of areas like manufacturing engineering, financial management, water resource management, power plants, artificial neural networks, distributed environment, ad hoc networks, clustering, etc.

II. METHODOLOGY

2.1.Black Hole Algorithm

In 1916, using Einstein's General Theory of Relativity, a German physicist named Karl Schwarzschild calculated that any mass could become a black hole if it were compressed tightly enough. In universe, one of the most extremely interesting and mysterious objects is black hole. In space, at a particular region of space-time (x, y, t) the gravitational force is very high and those regions are known as black holes. The term event horizon represents the boundary of a black hole. The density of the black hole does not allow any entity to cross or penetrate or escape, it absorbs and collapse the entity into it. The two most common types of black holes are: Stellar black hole and Super massive black holes. The characteristics of the black hole are defined by its properties mass (M), charge (Q) and angular momentum (J). Black hole algorithm starts with an initial population of candidate solutions to an optimization problem and an objective function that is calculated for them. At each iteration, the best candidate is selected to be the black hole and the rest form the normal stars. After the initialization process, the black hole starts pulling stars around it. If a star gets too close to the black hole it will be swallowed by the black hole and is gone forever. In such a case, a new star (candidate solution) is randomly generated and placed in the search space and starts a new search.

$$\text{Black hole}_i = \left\{ \begin{matrix} Mass\ (M) \\ Charge\ (Q) \\ Angular\ momentum\ (J) \end{matrix} \right\} \qquad i = 1, 2, 3, \ldots ,N \tag{1}$$

2.2.Ant Colony Optimization (ACO)

Ant colony optimization is a meta-heuristic for hard discrete optimization problems that was first proposed. ACO is one of the most efficient algorithms for solving QoS routing problem. The inspiring approach of ACO algorithms is the foraging behaviours of real ant. Generally, ants explore the surrounding area for food randomly. If an ant finds the food source then it carries it to the ant nest. While returning to the ant nest the ant deposits the pheromone on the path between the nest and food source. The pheromone attracts the other ants and other ants will follow the pheromone traces finally reach the food source. Whenever each ant travels from food source to nest it leave the pheromone trail. If more than one path exists between the food source and ant nest, the ants will select the path with high pheromone concentration. The pheromone is used by the ants for communication. This ideology is implemented in artificial ant colonies in order to solve discrete optimization problems such network routing. Most routing methods used ACO just deal with one parameter and considered the other important parameters like delay and delay jitter as constraints problem.

2.3.Particle Swarm Optimization (PSO)

Particle swarm optimization is a well-known meta heuristics population-based algorithm. It is a powerful stochastic optimization technique inspired by the collective behaviour of swarms such as schooling and bird flocking. The PSO algorithm considers each bird as a node during the initial formation of solution space. A node movement is affected by its position, group's position and inertia. The PSO algorithm handles multiple nodes in the solution space, where the position, velocity, and other parameter values are different for each node. In every iteration, each node exchanges its positional values and velocity with the neighbouring nodes, and this paves the way to update the solution. PSO is very easy to understand and implement. It is used in various domain like, modern structural engineering, civil infrastructure systems, traffic accident forecasting, mobile object tracking, power production system, energy management system, medical image analysis, and etc.

2.4 Fuzzy Algorithm

The truth value of variables in fuzzy logic may be any real number between 0 and 1. When dealing with the idea of partial truth, where the truth value can range from completely true to completely false, this technique is used. In contrast, only the integer values 0 or 1 are permitted as the truth values of variables in Boolean logic. Fuzzy logic is based on the idea that people frequently base their decisions on incomplete and non-numerical information. Mathematical methods for representing ambiguity and imprecise information include fuzzy models or sets (hence the term fuzzy). These models are capable of recognizing, representing, manipulating, deciphering, and using ambiguous and uncertain data and information. In MANET, fuzzy logic is used to make accurate decisions based on available criteria. It cuts down on the amount of time it takes to set up a connection. For determining control actions using fuzzy logic reasoning, the fuzzy control system includes a fuzzifier, fuzzy knowledge base, rule-based decision, and defuzzifier. Because the system's inputs and outputs are frequently crisp values, the fuzzification and defuzzification processes are utilized to convert them to and from fuzzy representations.

2.4.LSTM

Long Short-Term Memory Networks, more commonly referred to as "LSTMs," are a unique class of RNN that can recognize long-term dependencies. Intentionally, LSTMs are created to avoid the long-term dependency issue. All recurrent neural networks take the shape of a series of neural network modules that repeat. This repeating module in typical RNNs will be made up of just one tanh layer. The bidirectional LSTM neural network, which uses forward and backward time series to get available information of timestamps in the past and future, provides more local information to the network than the ordinary LSTM neural network, improving the network's ability to predict outcomes. The sensory data gathered by nodes in wireless sensor networks has regional characteristics; as a result, the distribution patterns of the sensory data from various nodes are similar. Similar to how different sensory data from the same node are correlated, there is a positive or negative correlation between different sensory data.

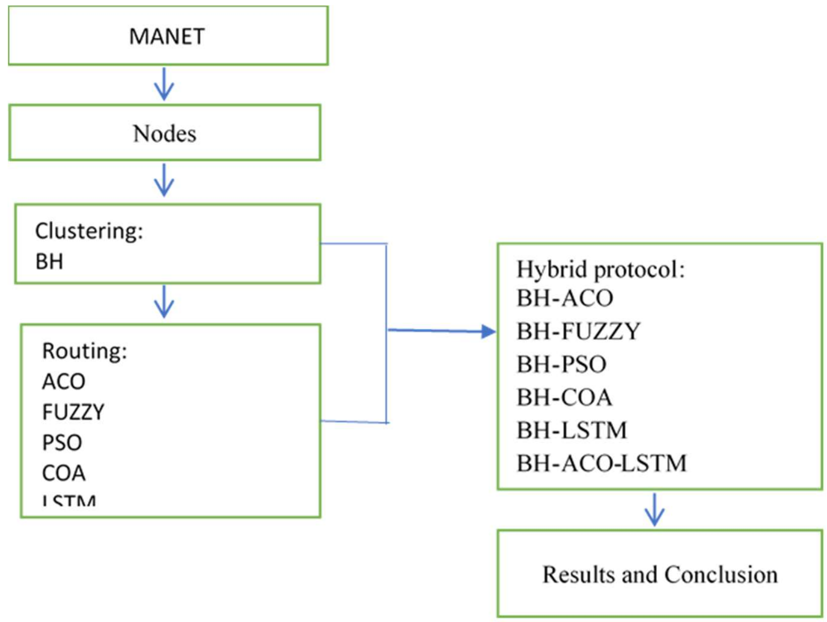

Fig 1 Block diagram of proposed algorithm

MANET can be created anywhere anytime without requiring any network infrastructure, it functions independently and it does not depend on any central control devices also it is easy to setup and operate. It is primarily applied in battlefield to direct the soldiers and other military vehicles. It is used in disaster management and emergency rescue operation during tsunami, earthquake, flood or fire. It can be used in homes and small offices to exchange the message without using internet also it is used to connect and communicate with different devices (mobile phones, notebooks, tablet, smart tv, etc..) wirelessly. This kind of networks is also known as multi-hop ad-hoc networks. Each mobile device will act as host as well as a router. Designing an intelligent QoS aware routing protocol is highly required to overcome the drawbacks and to improve the performance. Congestion control and link failure are the core issue in MANET it creates impact on network performance.

III. Related Work

3.1 Real-time Cluster Size Estimate

The RCSE is a recursive approach to estimate the population of the nodes. In the clustering technique, the calculation of population takes a lot of time when a greater number of nodes is available. Previous clustering methods have the potential to calculate each node at every iteration. Therefore, it takes lot of time to calculate the population size and also, it's considered as a drawback. To increase the efficiency of the algorithm an improvement is required in population calculation technique. In RCSE, the number of iterations required to calculate the cluster size has been greatly reduced.

$$D_k = \frac{1}{1+|| x_k - \mu ||^{2} + X - ||\mu||^2} \quad (2)$$

Where, D_k is the density of x_k. μ is the mean and X is the scalar product.

Mean and scalar product are calculated as:

$$\mu = \frac{1}{n} \sum_{i=1}^{n} x_i \quad (3)$$

$$X = \frac{1}{n} \sum_{i=1}^{n} x_i^2 \quad (4)$$

Where n is the total number of samples.
Fitness function calculation
Initial population is represented as

$$P(x) = \{x^t_1, x^t_2, x^t_3, \ldots\ldots\ldots, x^t_n\} \quad (5)$$

After initializing the population and fitness function is calculated at each iteration.
Fitness function for each iteration is calculated as

$$f_i = \sum_{i=1}^{size} \text{eval}(p(t)) \quad (6)$$

Fitness function for the black hole is calculated as

$$f_{BH} = \sum_{i=1}^{size} \text{eval}(p(t)) \quad (7)$$

Black hole absorption rate is calculated as

$$x_i(t) = x_i(t) + \text{rand} \times (x_{BH} - x_i(t)) \quad (8)$$

x_i^t and x_i^{t+1} are the locations of the i^{th} star at iterations t and (t + 1) respectively. In the solution space the location of the black hole is represented as x_{BH}. Based on the cost of location stars reach the location in the solution space. If the cost of a black hole is lower than the other locations then it reaches the black hole. Otherwise, the star reaches the new location. Sometimes the stars move to the location of the black hole and vice versa.
Probability of stars crossing the black hole radius
The stars which enter the radius of the black hole will be absorbed and destroyed. The stars cannot escape or return from the black hole. In each iteration it performs a new search in the solution space. It stops the iteration until all the stars are moved.
The radius of the black hole is calculated as

$$R = \frac{f_{BH}}{\sum_{i=1}^{N} f_i} \quad (9)$$

Where f_i is the fitness values of i^{th} star and f_{BH} is the fitness values of black hole.

3.2 Proposed Method

Phase I Apply Black Holes Algorithm and Fuzzy Set to improve clustering process

In basic blackhole algorithm, the gravity and Coulomb's (G, K) has constant values throughout the entire process in the algorithm, remains fixed and unchanged. This problem is resolved by introducing a Fuzzy Distance notion, consider the distance between black holes to determine G and K. In the proposed idea a Fuzzy function has been defined, for each gravity and Coulomb's constants, which receives distance between two black holes as input parameter and produces a membership degree for G and K values to be used. According to the defined fuzzy function, the lower the distance between two black holes, membership degree values for G and K would decline which results in strengthening local search and the higher the distance between two black holes, values obtained for G and K, would grow higher, causing reinforcement of the universal search. Fuzzy functions defined for G and K are illustrated in Figure 4 and corresponding Fuzzy rules are described below.

$$Fg_i = G\frac{m_{gbest} * m_i}{r^2}\, i = 1,2,\dots,N \tag{10}$$

$$Fq_i = k\frac{q_{lbest} * q_i}{r^2}\, i = 1,2,\dots,N \tag{11}$$

Fuzzy Rules:

1 If distance is low then G & K are low
2 If distance is medium then G & K are medium
3 If distance is high then G & K are high

Phase II Apply Ant Colony Optimization and LSTM algorithm to improve routing process

Initialization:

set t: = 0; // timer

set NR: = 0; //number of iterations

set NR_Mx; //maximum number of iterations

set C= τ_{ij} (t); // Initialize Pheromone for each link;

B-ants = n //backward ants start from the destination node.

Sn; // Source node

Dn; //Destination node

Intn; //Intermediate node

Streamline the network by applying the LSTM rules and check the LSTM cost for each link. Select the links which satisfies the LSTM rule and delete the links that do not satisfy rules.

L-Tab ((FCo): = 1); // Set the LSTM table (L-Tab) index (FCo as 1) to m ants;

For k: = 1 to m ants;

L-Tab ((FCo: = Sn)) // the node walked through by (F-ants) is recorded by L-Tab table L-Tab (F-ants).

Set FCo: = FCo+1 // Repeat until the fuzzy table is filled with values collected form the forward ant.

// Intermediate node (i) selects (j) next node at the time interval (t).

$$\max_{j=1,\dots q} \sum_{i=1}^{p} W_i(MF_i(d_{ij},t_i,b_i))$$

A random number within the interval is denoted by the variable (q) (0, 1). q1, q2, q3 are constants and q1 < q2 < q3. The variable s d_{ij} has pheromone value, Wi has relative amount of pheromone. When the forward ants (F-ants) pass through the path (i, j), the pheromone value (FCo) of the route will be updated in LSTM table (L-Tab). Finally, best paths are identified by the concentration of pheromone values from the LSTM table.

IV. RESULTS AND DISCUSSIONS

Compared to the base paper the proposed paper pay attention to the fitness of black holes. In the base paper the black hole selects the location with a random function. In the proposed paper LSTM is used to select the location it defines the fitness of the black hole and assigns a membership degree for the event horizon. It weeds the black holes with bad fitness because they are more susceptible to mutation.

Table 1 shows the True positive rate (TRP), true negative rate (TNR), false positive rate (FPR) and false negative rate (FNR) for proposed algorithm. The Blackhole LSTM (BH-ACO-LSTM) algorithm has a high TPR when the number of nodes is small and a low TPR when the number of nodes is large. When the number of nodes is large, the BH-ACO-LSTM algorithm very low false positive rates.

Tab 1 True positive rate (TRP), true negative rate (TNR), false positive rate (FPR) and false negative rate (FNR) for proposed algorithm

Algorithms	True positive	True negative	False positive	False negative
BH-COA	0.8	0.7	0.05	0.6
BH-FUZZY	0.9	0.8	0.06	0.2
BH-PSO	1.0	0.6	0.07	0.3
BH-ACO	1.2	1.0	0.08	0.4
BH-LSTM	1.4	1.2	0.09	0.5
BH-FS-ACO-LSTM	1.5	1.3	0.1	0.1

Table 2 shows the statistics of delay for different proposed algorithms with different nodes and Figure 3 shows the output of delay for different proposed algorithms with different nodes.

Tab 2 statistics of delay

Algorithms	50_Nodes	75_Nodes	100_Nodes	125_Nodes	150_Nodes	175_Nodes
BH-FS-ACO-LSTM	10%	12%	15%	18%	19%	20%
BH-LSTM	50%	85%	90%	50%	42%	45%

BH-ACO	70%	75%	85%	90%	29%	30%
BH-PSO	80%	60%	69%	70%	77%	78%
BH-FUZZY	59%	55%	68%	75%	60%	60%
BH-COA	90%	65%	50%	55%	84%	86%

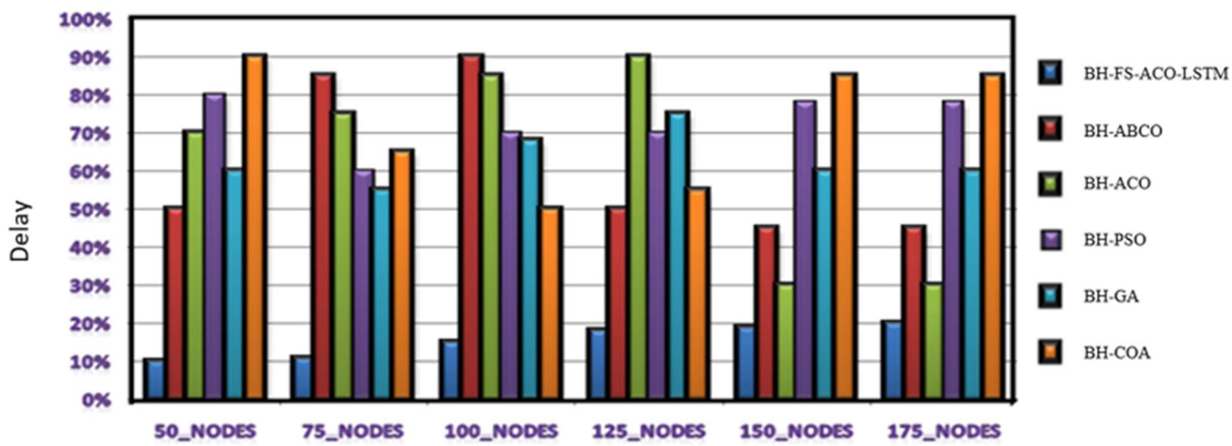

Fig 2 Output of Delay

Network delay describes the time it takes for a bit of data to move from one communication endpoint to another across the network. It is typically expressed in fractions or multiples of seconds. In Figure-2, BH-FS-ACO-LSTM algorithm has less delay time compared to other proposed algorithms for different nodes and BH-COA algorithm has high delay time compared to other proposed algorithms for different nodes. Table 3 shows the statistics of throughput for different proposed algorithms with different nodes and Figure 3 shows the output of throughput for different proposed algorithms with different nodes.

Tab 3 statistics of Throughput

Algorithms	50_Nodes	75_Nodes	100_Nodes	125_Nodes	150_Nodes	175_Nodes
BH-FS-ACO-LSTM	90%	92%	95%	96%	97%	99%
BH-LSTM	80%	81%	84%	86%	87%	88%
BH-ACO	70%	72%	74%	76%	77%	79%
BH-PSO	60%	65%	69%	72%	73%	75%
BH-FUZZY	56%	58%	60%	62%	65%	69%
BH-COA	53%	56%	57%	62%	66%	70%

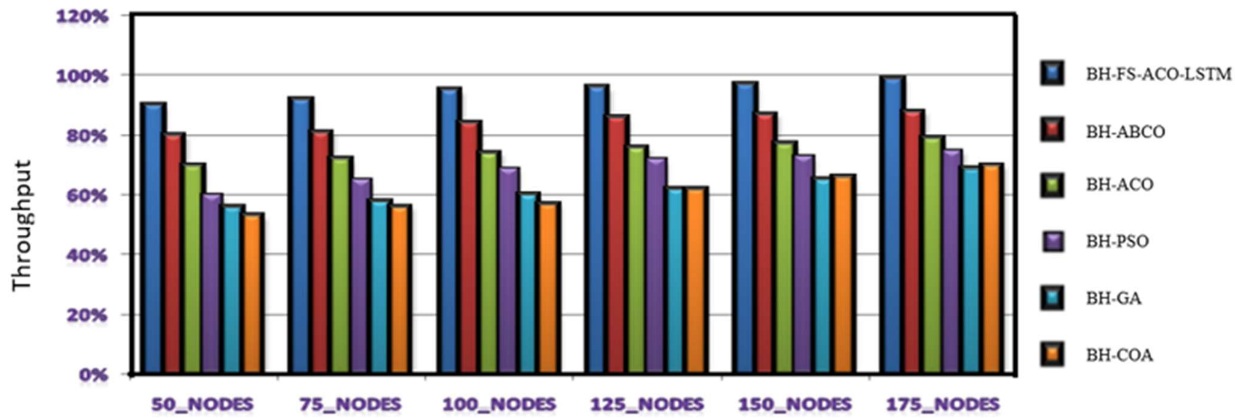

Fig 3 Output of Throughput

A term used in computers to describe how much work or information is being processed by a system. Especially significant in information storage and retrieval systems where throughput is measured in terms of accesses per hour or other units. The rate at which units move from beginning to end of the production process is known as the throughput rate. In Figure 3 BH-FS-ACO-LSTM algorithm has high throughput rate compared to other algorithms for different nodes and BH-COA has lower throughput rate compared to other algorithms for different nodes. Table 4 shows the statistics of MANET Lifetime for different proposed algorithms with different nodes and Figure 4 shows the output of MANET Lifetime for different proposed algorithms with different nodes.

Tab 4 statistics of MANET Lifetime

Algorithms	50_Nodes	75_Nodes	100_Nodes	125_Nodes	150_Nodes	175_Nodes
BH-FS-ACO-LSTM	100%	100%	100%	100%	100%	100%
BH-LSTM	90%	91%	94%	95%	96%	98%
BH-ACO	90%	92%	93%	94%	95%	97%
BH-PSO	70%	72%	75%	78%	79%	80%
BH-FUZZY	50%	55%	58%	59%	62%	63%
BH-COA	60%	63%	65%	69%	70%	72%

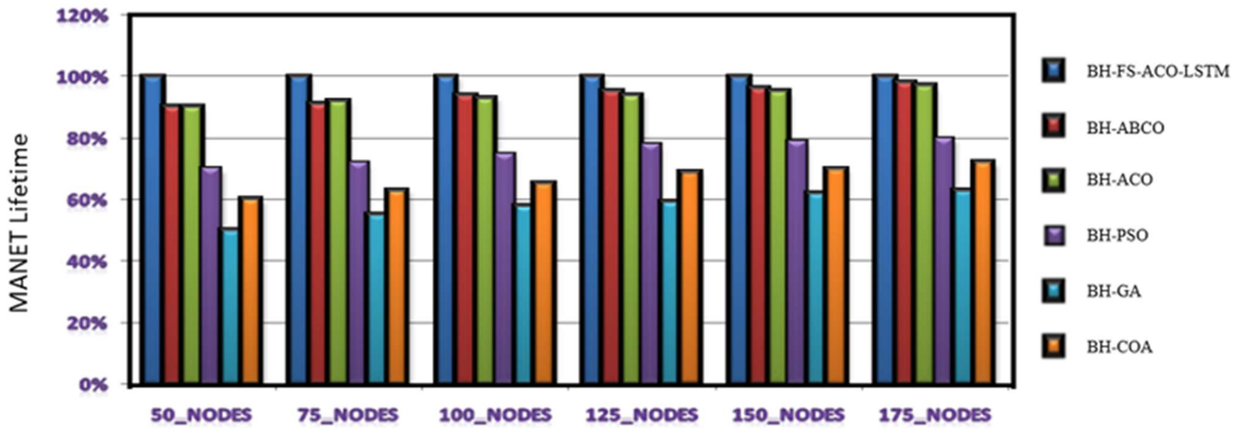

Fig 4 Output of MANET Lifetime

Link failure, node power failure, bandwidth restriction, and limited transmission power are significant problems in MANET. Energy-efficient protocol has developed into a very interesting and significant research area in order to solve these issues. Energy balance is a crucial issue in MANET because it can increase network lifetime. In Figure 4 BH-FS-ACO-LSTM has high MANET lifetime compared to other algorithms for different nodes and BH-Fuzzy has low MANET lifetime compared to other algorithms for different nodes. Table 5 shows the statistics of node Lifetime for different proposed algorithms with different nodes and Figure 5 shows the output of node Lifetime for different proposed algorithms with different nodes.

Tab 5 statistics of Node Lifetime

Algorithms	50_Nodes	75_Nodes	100_Nodes	125_Nodes	150_Nodes	175_Nodes
BH-FS-ACO-LSTM	80%	82%	85%	87%	89%	92%
BH-LSTM	70%	74%	76%	79%	80%	84%
BH-ACO	60%	61%	62%	64%	66%	68%
BH-PSO	50%	52%	55%	56%	53%	57%
BH-FUZZY	68%	69%	72%	73%	75%	78%
BH-COA	55%	58%	59%	60%	61%	64%

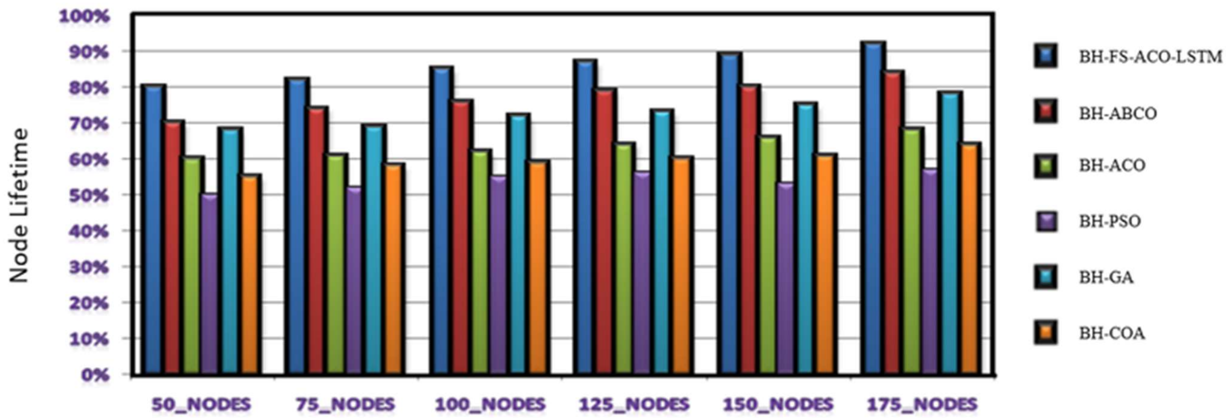

Fig 5 Output of Node Lifetime

In a larger network, a node is a component or a data point. Depending on networking, node can be a few different things. A node in networking can be a communication endpoint, a connection point, or a redistribution point. The period of time before the first node in the network runs out of energy is referred to as the network lifetime. In Figure 5 BH-FS-ACO-LSTM has high node lifetime compared to other algorithms for different nodes and BH-PSO has low node lifetime compared to other algorithms for different nodes. Table 6 shows the statistics of energy consumption for different proposed algorithms with different nodes and Figure 6 shows the output of energy consumption for different proposed algorithms with different nodes.

Tab 6 statistics of energy consumption

Algorithms	50_Nodes	75_Nodes	100_Nodes	125_Nodes	150_Nodes	175_Nodes
BH-FS-ACO-LSTM	8%	10%	12%	14%	15%	16%
BH-LSTM	15%	20%	25%	30%	35%	38%
BH-ACO	20%	25%	30%	35%	40%	45%
BH-PSO	50%	55%	65%	68%	70%	72%
BH-FUZZY	40%	45%	50%	70%	75%	80%
BH-COA	80%	85%	80%	90%	94%	98%

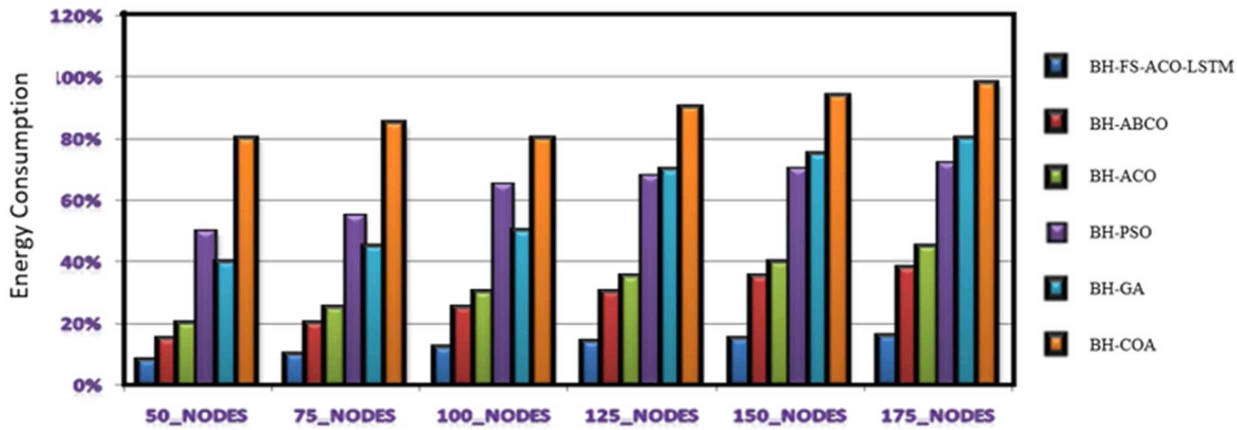

Fig 6 Output of Energy Consumption

The introduction of new generations of cellular technology, with better spectral efficiency, advanced hardware with lower power consumption, and also many energy-saving features introduced in mobile networks, has improved the energy performance of mobile networks over the years. Each node's energy consumption during packet transmission is used to calculate the total energy used by the entire network. In Figure 6 BH-FS-ACO-LSTM has low node energy consumption compared to other algorithms for different nodes and BH-COA has high energy consumption compared to other algorithms for different nodes. Table 7 shows the statistics of residual energy for different proposed algorithms with different nodes and Figure 7 shows the output of residual energy for different proposed algorithms with different nodes.

Tab 7 statistics of residual energy

Algorithms	50_Nodes	75_Nodes	100_Nodes	125_Nodes	150_Nodes	175_Nodes
BH-FS-ACO-LSTM	50%	60%	65%	70%	75%	80%
BH-LSTM	60%	65%	68%	75%	80%	85%
BH-ACO	40%	46%	57%	48%	63%	64%
BH-PSO	36%	47%	55%	60%	74%	76%
BH-FUZZY	66%	73%	68%	71%	79%	65%
BH-COA	20%	14%	5%	25%	17%	59%

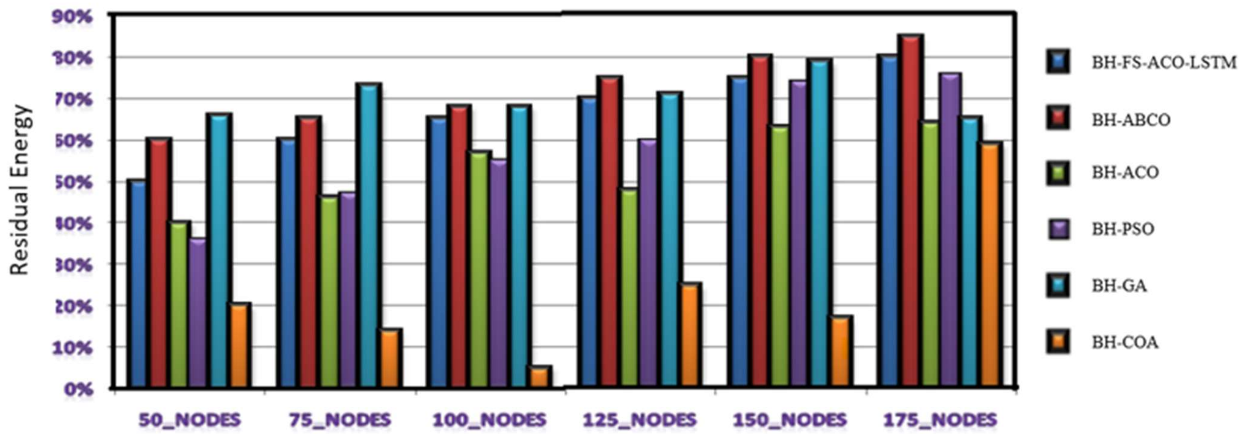

Fig 7 Output of residual energy

By adding up the energy lost while the node was in each state, the residual energy of the node can be calculated. Even though it is a decreasing function, decay heat has the potential to cause harm on its own. In Figure 7 BH-FS-ACO-LSTM has the third highest residual energy compared to other algorithms for different nodes and BH-COA has low residual energy compared to other algorithms for different nodes.

V. CONCLUSION

The proposed algorithm, improves the stability of a cluster and performs quality of service (QoS) aware routing in MANET. In the basic black hole algorithm, there is a phase with name Hawking radiation. In this phase the position of some black hole changes a little. This phase as equal mutation in genetic algorithm. We proposed a fuzzy Hawking radiation for these phases. The experimental results on different benchmarks show that the performance of the proposed algorithm is better than basic blackholes algorithm (BH). It outperforms efficient routing decisions by considering multiple parameters. Finally, integrating the Ant Colony Optimization (ACO) algorithm with LSTM would be an appropriate choice for improving QoS routing in MANET, also it handles the various uncertainties of MANET in a timely format. It outperforms efficient routing decisions by considering multiple parameters. The simulation result of this algorithm proves that it has higher throughput, reduced End-to-End delay, less routing overhead, and increased packet delivery ratio than the other algorithms such as

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