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Article

Efficient Optimal Routing Algorithm Based on Reward and Penalty for Mobile Adhoc Networks

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Abstract: Mobile adhoc networks have grown in prominence in recent years, and they are now utilized in a broader range of applications. The main challenges are related to routing techniques that are generally employed in them. Mobile Adhoc system management, on the other hand, requires further testing and improvements in terms of security. Traditional routing protocols, such as Adhoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR), employ the hop count to calculate the distance between two nodes. The main aim of this research work is to determine the optimum method for sending packets while also extending life time of the network. It is achieved by changing the residual energy of each network node. Also, in this paper, various algorithms for optimal routing based on parameters like energy, distance, mobility, and the pheromone value are proposed. Moreover, an approach based on a reward and penalty system is given in this paper to evaluate the efficiency of the proposed algorithms under the impact of parameters. The simulation results unveil that the reward penalty-based approach is quite effective for the selection of an optimal path for routing when the algorithms are implemented under the parameters of interest, which helps in achieving less packet drop and energy consumption of the nodes along with enhancing the network efficiency.

Keywords: Routing; optimization; reward; penalty; mobility; energy; throughout; pheromone

1 Introduction

Wireless networks have become the most crucial aspect of today's wireless communication to exchange information. The rapid advancements in wireless networking technologies have drastically modified the communication and networking world and have led to the infrastructure-less networking named Mobile Adhoc Networks (MANETs) [1]. Nodes in MANETs are connected by wireless connections, and they are free to move in any direction. The appealing qualities of MANETs enable to build up a network in emergency scenarios, where the infrastructure is not accessible or not viable. Because of their attractiveness and potential for the future, MANETs face a number of difficulties that must be solved. There is a presumption that all nodes will cooperate in MANET's routing protocols, but there are instances when the nodes misbehave or act selfishly because of specific difficulties, such as an open structure and limited energy supply. Actually, it is vital to have the communication devices being energy efficient in order to reduce the growing foot prints of carbon [2–6]. The traditional routing protocols such as Adhoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR) use the hop count as a measure of the distance between two nodes. To overcome the gaps of traditional routing protocols, bio inspired approach such as Ant colony optimization is also used [7]. It analyzes the distance based on the pheromone value. This is a more appropriate measure than the hop count. Furthermore, Ant Colony Optimization (ACO) selects the paths based on pheromone levels deposited by the ants without considering the remaining energy and speed of the nodes.

The extremely dynamic nature of MANETs frequently results in unpredictability in the network architecture, increasing the difficulty and complexity of routing between mobile nodes. The primary goal of ad-hoc network routing protocols is to create correct and efficient routing between a pair of nodes in order to ensure reliable and timely message delivery [8–11]. There are some other issues in the MANETS like: Limited energy, electronic hardware constraints [12,13], and the issues of energy. Thus, nodes mostly follow reactive routing protocols, such as AODV, and DSR. It creates the paths using the broadcasting of the request packets [14]. The broadcasting itself is an energy depletion process. Therefore, if the nodes with lesser energy get selected in the routing path, they may die out and lead to the loss of data. The second concern is the mobility of the nodes, which often leads to topological changes in the network. The path that exists at one moment in time may not be available in the other moment. This will initiate the route maintenance phase of the reactive routing protocol, which again calls for the broadcasting of error packets. Lastly, it is the decentralized nature of the network, where any attacker can compromise any node in the network and intentionally steal the data.

The main contributions of this paper are summarized as follows:

- It focuses on the role of optimization techniques for enhancing their effectiveness by considering various applications where it is being deployed in MANETS.
- The designing of various algorithmic approaches based on the optimal routing using the concept of a reward and penalty system.
- It analyzes the proposed algorithms under various network parameters in order to justify their significance.
- It also provides the simulation-based evaluation of the proposed algorithms for measuring their effectiveness.

The rest of the paper is organized as follows: The Section 1 of the paper introduces MANETs and their importance of optimization in routing. Section 2 of the paper discusses related work on various techniques for optimum routing in MANETs. The suggested optimum routing strategy in the form of algorithms is provided in Section 3 of this article, and the implementation of the proposed algorithms is presented in Section 4 of this paper. Section 5 of the paper presents the results and analysis. In Section 6, the conclusion is provided, and future work is highlighted in Section 7.

2 Related Work

Many researchers have worked in the direction of routing based on optimization approaches. The major observations and the challenges pertaining to their work are presented in a well-defined manner in this section. The authors suggested a novel routing technique in [15] to deal with the limited power resources of mobile networks. Next-hop availability, which estimates the likelihood of locating the best available next hop to reach a reactive ant and data packet target, has been utilized for a number of purposes. The optimization factors were the number of hops, travel time, and remaining energy in the batteries. Later on, some authors [16] suggested a method for the use of backup paths or multi-way for current failure recovery protocols. The technology ensures more secure communication channels, especially for MANET applications. Nevertheless, in the case of MANET connection failure, research on these multi-path protocols is centered on stability. In the case of a node failure, authors extend such protocols to ensure communication stability. Ad-hoc routing system suggested by Ali et al. [17] employ ACO approach and several disjoint paths to maximize efficiency and reliability. The proposed protocol is compared to the AODV Routing Protocol's performance in each of these areas. This operation is carried out every time.

The probabilistic multi-way routing algorithm [18] integrates factors such as signal force in the route measurements in order to avoid connection breaks before they occur. The algorithm updates the fitness function to select a particular path based on the congestion calculation and energy level at each node. The results of the simulation show that the new adhoc is a robust algorithm and is adaptable to the above-mentioned improvements in DSR. According to Moujahid et al. [19], an ACO method can be implemented in MANETs to tackle the routing problem. These algorithms are divided into proactive (table driven) and reactive techniques, as well as hybrid approaches (a combination of the two). Moreover, the authors [20] introduced a secure check- pointing technique that uses an ACO-based trust model to choose cluster head and gateway nodes. The ACO method is used to determine if nodes are available and whether they are selfish or malevolent. C programming is used to simulate the entire MANET ecosystem.

In a unique method, one of the authors [21] combined a Particle Swarm Optimization (PSO) with an ACO algorithm to increase the performance. To verify the novel hybrid technique (PSO–ACO), TSP benchmarks and empirical data are used to determine the best completion time. There is also a method based on ACO [22] that may be used to allocate channels to MANETs in order to achieve high spectral efficiency. To maximize spectrum usage and minimize interference, multi-objective functions are used. The results from grouping genetic algorithms are compared to the ACO-based method's convergence behavior and performance. "Segment Aware Rate Adaption (SARA)," a novel ACO-based protocol, was suggested and implemented by Mohsen [23].

The researchers provide a mixed approach for MANET routing optimization using ACO and cuckoo Search [24]. The use of the Adhoc on Demand Distance Vector (AODV) protocol is a part of the proposed optimization technique. The suggested method optimizes the AODV for delays and costs. In a 1000 m $\times$ 1000 m space, the nodes are scattered using OPNET. Some authors propose Improved Ant Colony based Multi constraint QoS Energy Routing (IAMQER) [25] as a new, more efficient, and more efficient QoS energy-saving routing method for designing multi-constrained Quality of Service (QoS) routes [26,27], while simultaneously increasing throughput and reducing energy usage. It is a heuristic method used to calculate the most efficient path. The proposed IAMQER technique helps to balance the relationship between the network output and energy usage. Therefore, it enhances the network performance in multi-constrained QoS routing.

It was proposed by Zhang et al. [28] that an Ant Colony Optimization Based Multi Routing Algorithm (ACOBMRA) system might utilize the QoS of the multicast based ACO routing in MANETs. The suggested technique does not create the multicast mesh mindlessly. As an alternative, it is based on each link's pheromone value. Their effectiveness differs a little between the Orthogonal Directional Multi Routing Protocol (ODMRP) and ACOBMRA. In [29], the authors proposed a hybrid algorithm for ACO, Search Access (SA), mutation provider and the local search. The SA and mutation operator have been used from time to time to increase the population diversity of the ants and to effectively leverage the current search area using the local search. It was proposed by Hao et al. [30] that Actor - Critic with Experience Centric Replay (ACECR) can be used in MANETs. The ACECR's routing protocol analyzes the average and lowest energy of pathways to determine the best route with the most energy. Janakiraman [31] suggested an enhanced optimization of the ant colony algorithm, consisting of introducing both an elitist and a weakened random factor and strategy. The random factor gives a search path within the optimum track area. A Minimal Energy Consumption with Optimized Routing (MECOR) was suggested by Sun et al. [32], and it is a routing protocol for mobile devices. Using the mathematics and signaling features of mobile nodes in MANET, MECOR proposes a straightforward communication approach for addressing MANET's energy and routing concerns at once. The routing method for Wireless Sensor Networks (WSN) was developed by Roy et al. [33] to maximize efficient routing and offer a trustworthy path for sensor networks. An effective transmission path may be selected by using the recommended approach. In WSNs, this effort focuses largely on enhancing the finding of the optimal path between the source node and the base station. An intelligent ant with some knowledge of the nodes in the route path finds the optimal route path, and the modified ACO is used to determine the best path.

One of the authors [34] presented the Fuzzy Dynamic Cluster Routing Protocol (FDCRP) which integrates the trusted waterfall architecture and attempts to overcome all of the common difficulties with MANETs. The suggested approach lowers the time and energy spent on this activity. Thus, the dynamic broadcasting approach aids in the formation of clusters generated dynamically as nodes migrate from one area to the other. This hybrid routing protocol based on ACO and Particle Access Optimization (PAO), B-iHTRP, was developed by the authors. The perceptive ants are used as a part of bio-inspired iHTRP's routing protocol to proactively maintain the ZRTab and reactively identify routes to locations outside of zones on demand [35]. A novel route selection method integrating AODV with ACO was suggested by Nayyar et al. [36] in order to enhance MANET QoS. The path pheromone value is based on the mechanism of the AODV ant colony and is used to identify the optimal route for data transmission. The pheromone value is determined by considering the end-to-end dependability, congestion, hop count and the residual energy of nodes in the proposed task. For data packet transmission, the route with the greatest pheromone value is chosen. The simulation results reveal a significant improvement in the performance over existing routing algorithms such as AODV, Dynamic Source Routing (DSR), and Enhanced-Ant-DSR. In order to improve the selection of available routes, authors [37] have developed a reliable and energy effective algorithm based on the concept of Learning Automata (LA) theory. Nath et al. [38] has suggested a hybrid ACO and Ant Bee Colony optimization technique for the successful cluster head selection that overcomes the mutual limitations of ACO and ABC. The problems associated with the stagnation of the ACO intensification process are prevented by the use of exploration agents.

Using the DS defensive theory, Alappatt et al. [39] presented an ant-colony routing method. Using an ad hoc mobile QoS method, Singh et al. [40] combine ant colony with Orthogonal Length Source

Routing (OLSR) to find stable routes between source and destination nodes. Routing is one of the biggest difficulties with MANET because of the variety of nodes that may be used. To improve QoS, Sampath et al. [41] has proposed Genetic Algorithm-Any Colony Optimization (GA-ACO). They have presented an agent-driven multicast routing method that employs hybrid GA & ACO approaches for optimizing variables. Some researchers [42] have demonstrated the optimization performance of the technique to address tough optimization challenges. They compare optimization performance with the basic ACO technique to solve the Travelling Salesman Problem (TSP). In tackling these TSP standard examples and gate assignment issues, the suggested algorithm may gain optimal value for optimization. Khan et al. [43] introduced the protocol, which is a multipath routing based on ACO approach. The packets are transport from the source to the destination, and they are controlled by ants in this protocol. The major aim of the routing approach was to select the best route for routing jobs from the source to destination while considering multipath links.

Ahmad Khan et al. [44] offer a hybrid model for jamming mitigation and energy monitoring that combines the MOACO and double Q-learning models. The concept was proposed using the Internet of Things (IoT) paradigm, which comprises data aggregation and energy-constrained devices. To minimize any iterative dependencies, the firefly method works in conjunction with the Levy Flight induced ACO to resolve delays and provide better routing optimization in unstable condition. There is an ACO hybrid method that combines ACO with Binary PSO to enhance the network's life span proposed by Alappatt and Joe Prathap. The nodes are switched between the active and sleep phases with the ACO assistance. A security-conscious and fuzzy colony optimization is developed by Singh and Sharma. Meanwhile, the node reliability values are dynamically updated by the fuzzy logic system. The routing protocol has been followed using the NS-3 simulator, and several tests were performed in MANET and Vehicular Adhoc Network (VANET) situations. Using the Glowworm Swarm Optimization (GSO) method, some authors created effective load balancing and routing algorithms. To manage sensor node energy consumption, this LBR-GSO utilizes a pseudo-random route finding method and an improved pheromone trail-based updating technique. To improve route establishment, it employs an effective heuristic update method based on cost effective energy measurement. Finally, an LBR-GSO cast-off energy-based broadcasting method has been developed to eliminate energy consumption caused by the control overhead.

Therefore, as per the above discussed literature work, it can be seen that researchers have worked to enhance the efficiency of routing in MANETS using some optimization methods, but still, there are some challenges on which further work needs to be carried on. Most of the work has been carried out by considering the metrics such as throughput, delay, packet drop and energy efficiency.

3 Proposed Optimal Routing Technique

Routing in a MANET is a difficult task due its dynamic configuration as well as the shortage of a current fixed infrastructure. This work trying to discover the optimal way to transmit the packets and extend the network life as much as possible. Here in this section, firstly, the mathematical model is presented for the proposed approach and then the algorithms based on the reward penalty system are introduced.

3.1 Mathematical Model Representation

As a result of the mathematical model, a natural occurrence is reduced to a formal numerical statement through the use of a casual structure. To maximize the path from source to destination, mobility is one of the most critical factors. Increased routing overhead is caused by a breakdown of these nodes, as they are essential for maintaining routes where control messages need to be retested.

The pheromone value is collected through the agents in each intermediate node. The node with the greatest pheromone value is considered the best path to the destination, as specified in Eq. (1).

$$Best\ Path = \frac{2}{Time\ between\ Nodes\ A\ to\ B} + (Hop\ Count * Avg.\ Time) \tag{1}$$

The energy model depicts the maximum energy level of the network's nodes. A node has a specific quantity of energy at the start of its life. Each packet that takes part in communication releases some amount of energy. As a result, the energy at the beginning of a node is decreased at any given moment. A node's residual energy is what remains after it has received or sent packets at any given moment. Data transmission will be delayed if a node's residual energy is insufficient to send the data to its destination. Thus, node residual energy reflects the node's lifespan. The more energy a node has, the longer it is involved in the network.

$$E.Tx = E.elect * L * D(pow, 2) \tag{2}$$

$$E.Rx = E.elec * L \tag{3}$$

By applying these formulas, the maximum residual energy of nodes is calculated. The more energy node possesses, the more its lifetime in the network.

E.Tx: Total energy needed to transmit L bits of packet over a link.

E.elect: Basic energy needed to run the transmitter.

E.Rx: Total energy needed for receiving L bits of packet over a link.

D: distance, *L:* No of Bits.

Radio Energy Model helps in calculating how much energy is consumed in transmitting and receiving L bits of message over a distance D.

It is important to provide a short path among the source as well as the destination. The minimum distance between sources to destination is calculated by using the following Eq. (4) as presented.

$$Min\,distance = sqrt\,(pow\,(x2 - x1) + pow\,(y2 - y1) \tag{4}$$

If fast moving mobile nodes are selected while creating the route, the nodes can move to a different location very quickly. There must be relatively fewer mobile nodes on the optimized route in the system, as represented in Eqs. (5) to (7).

$$Mobility\ of\ node = int(rand\,(.) * 70) \tag{5}$$

$$New\ Location\ of\ node = Pre\ pos + new\ pos \tag{6}$$

$$Speed = int(rand\,(.) * 5) \tag{7}$$

One of the major goals in developing this hybrid technique is to determine the residual node energy, Euclidean distance, and mobility.

3.2 Reward Penalty Approach for Optimal Routing

In order to make the proposed approach more effective, an approach based on reward and penalty is introduced for the selection of optimal path by the nodes involved in the routing process.

In the beginning, all arcs are allotted the same quantity of pheromone. In order to calculate the chance of moving to the next node, ant 'k' uses the pheromone trail to calculate the probability of moving to node 'j'. The chance that how ant goes from node 'i' to node 'j' is determined by Eq. (8).

$$p_{i,j} = \frac{\left(T_{i,j}^{\propto}\right)\left(\eta_{\mathrm{i,j}}^{\beta}\right)}{\sum \left(T_{i,j}^{\propto}\right)\left(\eta_{\mathrm{i,j}}^{\beta}\right)} \tag{8}$$

$\tau_{\mathrm{i,j}}$ signifies quantity of pheromone on the edge i,j

α describe that how to balance the effect of $\tau_{\mathrm{i,j}}$

$\eta_{,\mathrm{i,j}}$ is the necessity of the edge i, j (usually $1/d_{\mathrm{i,j}}$)

β describe that how to balance the effect of $\eta_{,\mathrm{i,j}}$

are the pheromone value as it cross the (i, j) arc.

Calculate pheromone amount using Eq. (9).

$$\tau_{ij} = (1 - \rho)\, \tau_{i,j} + \Delta\, \tau_i \tag{9}$$

Here τ_{ij} are the edges on which pheromone is concentrated, and ρ signifies evaporation rate of pheromone. It's usually given by Eq. (10) and is called $\Delta\, \tau_{i,j}$

$$\Delta^{T_{i,j}^{k}} = \left\{ \frac{1}{Lk}\ if\ ant\ k\ on\ edge\ i,j \right\} \tag{10}$$

Here, L_k represents the cost of the k^{th} ant's tour.

The route with many reward points is intended as the suitable/optimized route for the transfer of data from the source to the destination node.

3.2.1 Reward Penalty System Based on Pheromone and Energy

Here, this research has presented the proposed reward penalty approach based on the pheromone value, and the residual energy for the optimal routing along with the algorithmic steps that are involved in the process. The proposed system for reward and penalty is represented in Eqs. (11) and (12).

$$f_{ph}\,(i) = max \left\{ \sum\nolimits_{j=1}^{m_{i1}} ph_{j,i1}, \sum\nolimits_{j=1}^{m_{i2}} ph_{j,i1}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \sum\nolimits_{j=1}^{m_{ip}} ph_{j,ip} \right\} \tag{11}$$

$$f_{RE}\,(i) = max \left\{ \sum\nolimits_{j=1}^{m_{i1}} RE_{j,i1}, \sum\nolimits_{j=1}^{m_{i2}} RE_{j,i}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \sum\nolimits_{j=1}^{m_{ip}} RE_{j,ip} \right\} \tag{12}$$

Where, $f_{ph}(i)$ indicates the fitness level of i^{th} path in words of pheromone value deposited over the links constituting the path having *m* nodes,

$f_{RE}(i)$ indicates the fitness level of i^{th} path in words of the remaining energy of the nodes constituting the path having *m* nodes.

First of all this research is presenting the Algorithm 1 for the reward penalty system based on pheromone and energy.

Algorithm 1: Proposed algorithm on the basis of pheromone and energy

```
1. Suppose N is number of nodes; Nei is the neighbor set
        for i =1: N
            for j =1: Nei
2. Node (i) broadcasts FANTs to Nei (j)
3. Deposit pheromone over the link
4. Send Residual Energy R.E(i) to Neighbor
               if Nei (j) == destination
                       execute procedure BANTS ()
               else
    If Residual Energy of Neighbor > 0.9 * Average Residual Energy
                     continue broadcasting
    else
            Drop FANT
         End if
             End if
       End for
End for
5. Procedure BANTS ()
6. Trace back all the paths towards the source node
      for i = 1: P     // Here P is the count of paths formed
        Send backward ant
             Update pheromone
      End for
7. Arrange paths according to maximum pheromone value and maximum Residual Energy
        Initialize Reward and Penalty points; RP =1, PL = 1, Points =1
           For i=1:P
             RP(i) = RP(i) * Points
             Points = Points-0.1
          End for
8. Choose path with maximum reward points
9. Send data to destination node
```

3.2.2 *Reward Penalty Approach on the Basis of Pheromone, Energy and Distance*

The suggested reward penalty technique based on pheromone value, residual energy, and distance for optimum routing is described here along with the computational stages involved in the process. The proposed system for reward and penalty is represented through Eqs. (13) to (15).

$$f_{ph}(i) = max\left\{\sum_{j=1}^{m_{i1}} ph_{j,i1}, \sum_{j=1}^{m_{i2}} ph_{j,i}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \sum_{j=1}^{m_{ip}} ph_{j,ip}\right\} \tag{13}$$

$$f_{RE}(i) = max\left\{\sum_{j=1}^{m_{i1}} RE_{j,i1}, \sum_{j=1}^{m_{i2}} RE_{j,i}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \sum_{j=1}^{m_{ip}} RE_{j,ip}\right\} \tag{14}$$

$$f_{D}(i) = min\left\{\sum_{j=1}^{m_{i1}-1} D(j,j+1)_{i1}, \sum_{j=1}^{m_{i2}-1} D(j,j+1)_{i2}, \ldots\ldots\ldots\ldots\ldots\ldots\ldots \sum_{j=1}^{m_{ip}-1} D(j,j+1)_{i9}\right\} \tag{15}$$

$f_{ph}(i)$ indicates the fitness level of i^{th} path in words of pheromone value deposited over the links constituting the path having *m* nodes,

$f_{RE}(i)$ indicates the fitness level of i^{th} path in words of remaining energy of the nodes constituting the path having *m* nodes,

$f_d(i)$ indicates the fitness level of i^{th} path in terms of the Euclidean distance of the nodes constituting the path having *m* nodes.

First and foremost, this research proposes the second algorithm, as mentioned below.

Algorithm 2: Proposed algorithm on the basis of Pheromone, Energy and Distance

```
1. Suppose N is number of nodes; N_ei is the neighbor set
        for i =1: N
            for j =1: N_ei
2. Node (i) broadcasts FANTs to N_ei (j)
3. Deposit pheromone over the link
4. Send Residual Energy R.E(i) to Neighbor
5. Send Location coordinates to Neighbor
            if Nei (j) == destination
                    execute procedure BANTS ()
            else
         If Residual Energy of Neighbor > 0.9 * Average Residual Energy
                          continue broadcasting
          else
              drop FANT
         End if
             End if
       End for
End for
6. Procedure BANTS ()
7. Trace back all the paths towards the source node
   for i = 1: P            // Here P is the count of paths formed
   Send backward ant
   Update pheromone
End for
8. Arrange paths according to maximum pheromone value, maximum residual energy and minimum
euclidean distance
9. Initialize Reward and Penalty points; RP =1, PL = 1, Points =1
     For i=1:P
   RP(i)=RP(i) * Points
   Points = Points-0.1
   End for
10. Choose path with maximum reward points
11. Send data to destination node
```

3.2.3 Reward Penalty System Based on Pheromone, Energy, Distance and Mobility

Here, this paper has presented the proposed reward penalty approach based on the pheromone value, residual energy, distance and mobility for the optimal routing along with the algorithmic steps that are involved in the process. The proposed system for reward and penalty is represented in Eqs. (16) to (19).

$$f_{ph}(i) = max\left\{\sum\nolimits_{j=1}^{m_{i1}} ph_{j,i1}, \sum\nolimits_{j=1}^{m_{i2}} ph_{j,i}, \ldots\ldots\ldots\ldots\ldots\ldots \sum\nolimits_{j=1}^{m_{ip}} ph_{j,ip}\right\} \tag{16}$$

$$f_{RE}(i) = max\left\{\sum\nolimits_{j=1}^{m_{i1}} RE_{j,i1}, \sum\nolimits_{j=1}^{m_{i2}} RE_{j,i}, \ldots\ldots\ldots\ldots\ldots\ldots \sum\nolimits_{j=1}^{m_{ip}} RE_{j,ip}\right\} \tag{17}$$

$$f_{D}(i) = min\left\{\sum\nolimits_{j=1}^{m_{i1}-1} D(j,j+1)_{i1}, \sum\nolimits_{j=1}^{m_{i2}-1} D(j,j+1)_{i2}, \ldots\ldots\ldots\ldots\ldots\ldots \sum\nolimits_{j=1}^{m_{ip}-1} D(j,j+1)_{ip},\right\} \tag{18}$$

$$f_{m}(i) = min\left\{\sum\nolimits_{j=1}^{m_{i1}} M_{j,i1}, \sum\nolimits_{j=1}^{m_{i2}} M_{j,i}, \ldots\ldots\ldots\ldots\ldots\ldots \sum\nolimits_{j=1}^{m_{ip}} M_{j,ip}\right\} \tag{19}$$

$f_{ph}(i)$ indicates the fitness level of i^{th} path in terms of pheromone value deposited over the links constituting the path having m nodes,

$f_{RE}(i)$ indicates the fitness level of i^{th} path in terms of remaining energy of the nodes constituting the path having m nodes,

$f_{d}(i)$ indicates the fitness level of i^{th} path in terms of Euclidean distance of the nodes constituting the path having m nodes.

$f_{m}(i)$ indicates the fitness level of i^{th} path in terms of mobility of the nodes constituting the path having m nodes.

Algorithm 3: Proposed algorithm based on pheromone, energy, distance and mobility

```
1. Suppose N is number of nodes; Nei is the neighbor set
        for i =1: N
            for j =1: Nei
2. Node (i) broadcasts FANTs to Nei (j)
3. Deposit pheromone over the link
4. Send Residual Energy R.E(i) to Neighbor
5. Send Location coordinates to Neighbor
6. Send mobility value to the Neighbor
                    if Nei (j) == destination
                                execute procedure BANTS ()
                    else
   If Residual Energy of Neighbor > 0.9 * Average Residual Energy
                                continue broadcasting
   else
                   Drop FANT
                End if
                End if
```

(Continued)

Algorithm 3: Continued

```
        End for
End for
7. Procedure BANTS ()
8. Trace back all the paths towards the source node
   for i = 1: P            // Here P is the count of paths formed
           Send backward ant
           Update pheromone
End for
9. Arrange pathways to get the larger pheromone value, the larger residual energy, the less Euclidean distance, and the most mobility.
10. Initialize Reward and Penalty points; RP =1 , PL = 1, Points =1
   For i=1:P
   RP(i) = CP(i) * Points
   Points = Points-0.1
        End for
11. Choose path with maximum reward points
12. Send data to destination node
```

4 Implementation of the Proposed System

The goal of this study is to determine the optimum method for sending packets, while extending life time of the network. It is achieved by changing the residual energy of each network node.

During the reactive path setup phase, FA (forward Ant) is produced by the source node for identifying numerous pathways to the node destination represented by a pheromone trail. On reaching the destination, BA (Backward Ant) is created with the aim of sending the route towards the source. By referring to Eq. (1), the results are interpreted as per the Table 1.

Table 1: Identified paths from 0 to 59 with pheromone

Path_no	Paths	Pheromone
0	59 46 43 33 5 0	24.264
1	59 47 43 33 5 0	26.3818
2	59 28 19 16 10 0	29.4939
3	59 17 27 16 10 0	40.7745
4	59 38 27 16 10 0	21.4332
5	59 39 30 35 10 0	32.6654
6	59 31 23 11 12 0	19.8573

According to Table 1 mentioned above, multiple paths have been discovered from 0 to 59 to the target node, among these paths, the path having a higher pheromone will be selected as an optimal path from the sender to the receiver. The path_no 3 is considered the optimal path having maximum pheromone. The energy depends on factors such as coding methods, modulation, filtering, signal use and multipath that depend on the transmission distance d, if the distance is less than 250 meters.

According to Table 2, multiple paths have been discovered from 0 to 59 to the target node, among these paths, the path having higher pheromone will be selected the optimal path from the sender to the receiver.

Table 2: Identified paths from 0 to 59 with pheromone and energy value

Path_no	Paths	Pheromone	Energy
0	59 17 14 6 2 0	37.3699	266.815
1	59 17 14 6 5 0	16.5447	266.97
2	59 17 14 6 10 0	15.6786	267.003
3	59 17 14 15 10 0	9.52103	267.02
4	59 17 14 16 2 0	10.9181	266.827
5	59 17 14 16 5 0	8.51908	266.982
6	59 17 14 16 10 0	6.93561	267.015

The Euclidian distance is calculated, and the results are interpreted in Table 3. According to Table 3, various routes from the sender to the target node have been identified ranging from 0 to 59.

Table 3: Identified paths from 0 to 59 with pheromone, energy and distance values

Path_no	Paths	Pheromone	Energy	Distance
0	59 17 14 6 2 0	37.3699	266.815	1031
1	59 17 14 6 5 0	16.5447	266.97	1045
2	59 17 14 6 10 0	15.6786	267.003	1129
3	59 17 14 15 10 0	9.52103	267.02	1108
4	59 17 14 16 2 0	10.9181	266.827	1013
5	59 17 14 16 5 0	8.51908	266.982	1076
6	59 17 14 16 10 0	6.93561	267.015	1067

However, this research requires a path that provides us with an ideal route with more pheromone, high energy, and lesser distance.

The method of compensation on the basis of reward penalty system is as follows:

- In comparison with others, the highest pheromone value direction is rewarded with more points.
- Further reward points are available on the route with nodes with the highest residual energy levels.
- There are more reward points on the shortest route.
- The opposite is true: they are punished for pathways with poor pheromone concentration, low remaining energy, and long journeys.

According to Table 4, the best path route is at Path no_0, calculated by applying a reward penalty approach.

Table 4: Results of reward penalty system depends on pheromone, energy and distance value

Path_no	Paths	Results
0	59 17 14 6 2 0	2.3
1	59 17 14 6 5 0	2.3
2	59 17 14 6 10 0	2
3	59 17 14 15 10 0	2.2
4	59 17 14 16 2 0	2.1
5	59 17 14 16 5 0	1.8
6	59 17 14 16 10 0	2

In Table 5, multiple paths have been discovered ranging from 0 to 59. From the Table 5, path no_0 contains more value of pheromone and provides the optimal route from the sender to the destination node. Path no_3 gives the highest energy, whereas Path no_4 points toward the lesser distance. However, this research requires a path that provides us with an ideal route with more pheromone, high energy, and lesser distance.

Table 5: Identified paths from 0 to 59 with pheromone, energy, distance and mobility

Path_no	Paths	Pheromone	Energy	Distance	Mobility
0	59 17 14 6 2 0	37.3699	266.815	1031	13
1	59 17 14 6 5 0	16.5447	266.97	1045	17
2	59 17 14 6 10 0	15.6786	267.003	1129	14
3	59 17 14 15 10 0	9.52103	267.02	1108	12
4	59 17 14 16 2 0	10.9181	266.827	1013	11
5	59 17 14 16 5 0	8.51908	266.982	1076	15
6	59 17 14 16 10 0	6.93561	267.015	1067	12

According to Table 6, the best path route is at Path no_4, which is calculated by applying a reward penalty approach based on higher pheromone level, higher energy, lowest distance value and less mobility. The different parameters that are evaluated for the given work are remaining energy, packet drop, packet delivery ratio, and throughput.

Table 6: Results of reward penalty system based on pheromone, energy, distance and mobility

Path_no	Paths	Results
0	59 17 14 6 2 0	3
1	59 17 14 6 5 0	2.7
2	59 17 14 6 10 0	2.5
3	59 17 14 15 10 0	2.9
4	59 17 14 16 2 0	3.3
5	59 17 14 16 5 0	2.4
6	59 17 14 16 10 0	2.8

5 Result Analysis and Interpretation

The simulation of the proposed approach is being done in NS2, and the various parameters that are taken into account are represented in the Table 7. When a source node needs to send data to the destination, it begins the broadcasting process through the network from Source Node 0 to Destination 60. The source node creates Forward Ant (FA) in order to identify multiple pathways to the destination, each of which is represented by a pheromone trail of varying quality, with the aim of finding the shortest path between the source and the target node. In Fig. 1 the nodes which are green in color represent one hop nodes that received route request packets from the source node. The process of broadcasting continues until the route to the destination is found.

Table 7: Simulation parameters representation for the proposed approach

Simulation parameters	Value
Routing protocols	AODV
Simulation time	25 s
Traffic type	CBR (UDP)
Model for propagation	Two ray ground
Model for mobility	Random waypoint
Energy model	Radio energy
Antenna	Omni directional
Interface queue (IfQ)	Drop tail
Packet size	512 Bytes

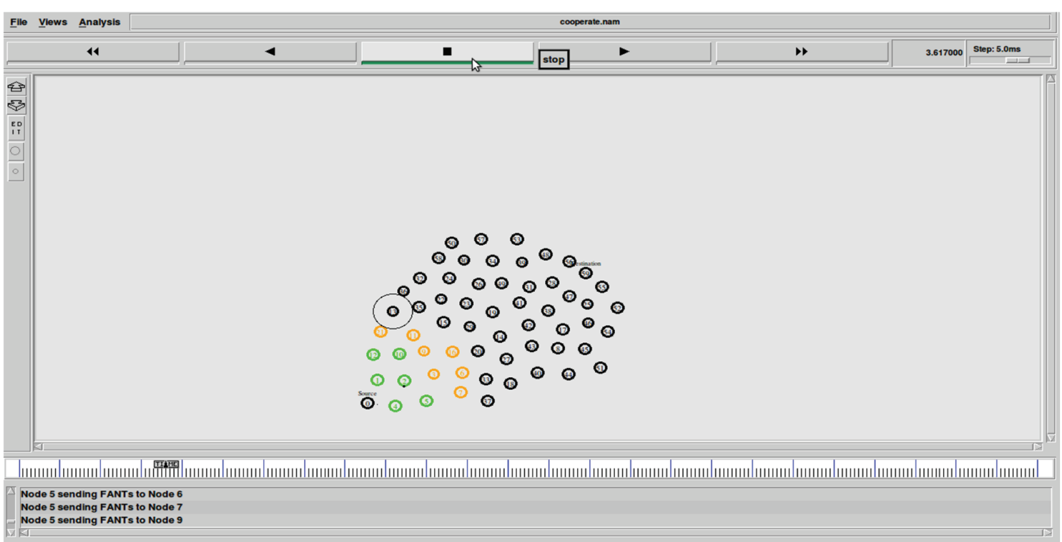

Figure 1: Shows results of source node 0 sending FANT to its neighbors

On reaching the route request to the destination, Backward Ant (BA) is generated with the objective of returning the route to the source, recording all nodes visited along the way, and updating the pheromone value at both the intermediate and source, as shown in Fig. 2. The Pheromone value of all the pathways through which the route request came will be calculated by the destination node.

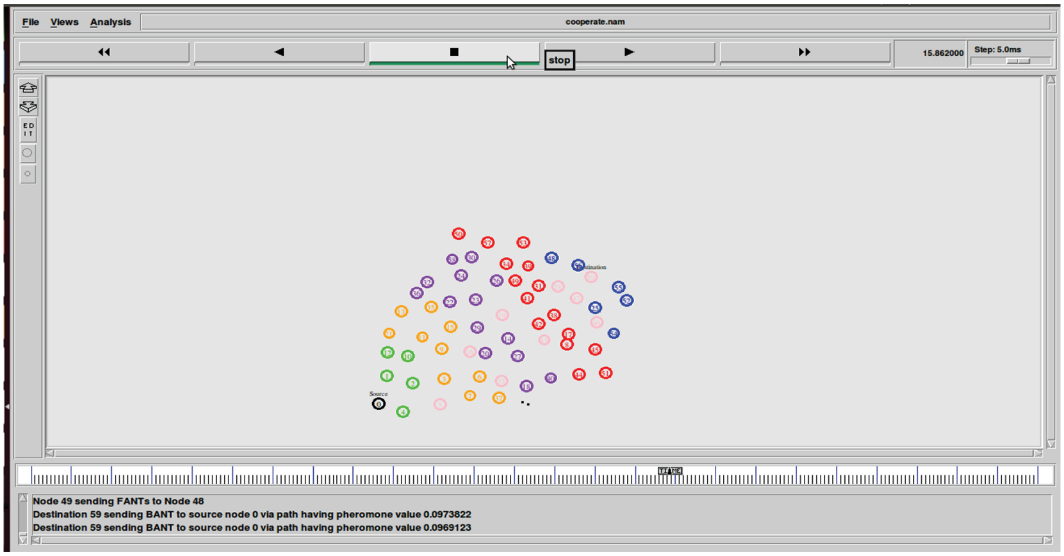

Figure 2: Shows results of BANT sending route back to source node with pheromone

Fig. 3 shows that the pheromone route with the highest values is chosen. This optimized path will be used by the source to transfer data to the destination node.

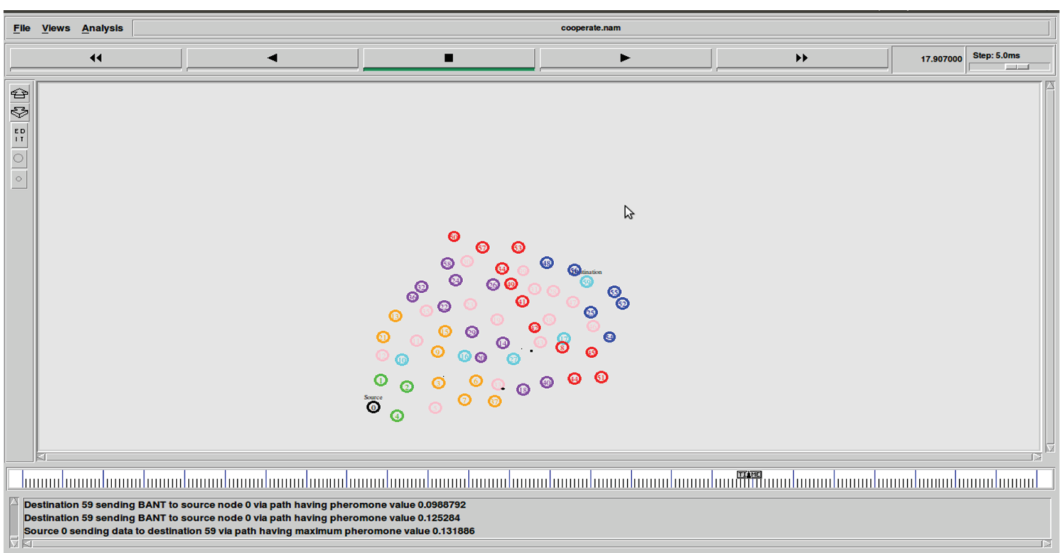

Figure 3: Shows results of destination sending BANT to source node having higher pheromone

When a source node needs to send data to a destination node, it initiates the broadcasting route request procedure in the network from source node 0 to destination 60. Fig. 4 the nodes which are green in color represent one hop nodes that received route request packets from the source node. The process of broadcasting continues until the route to the destination is found.

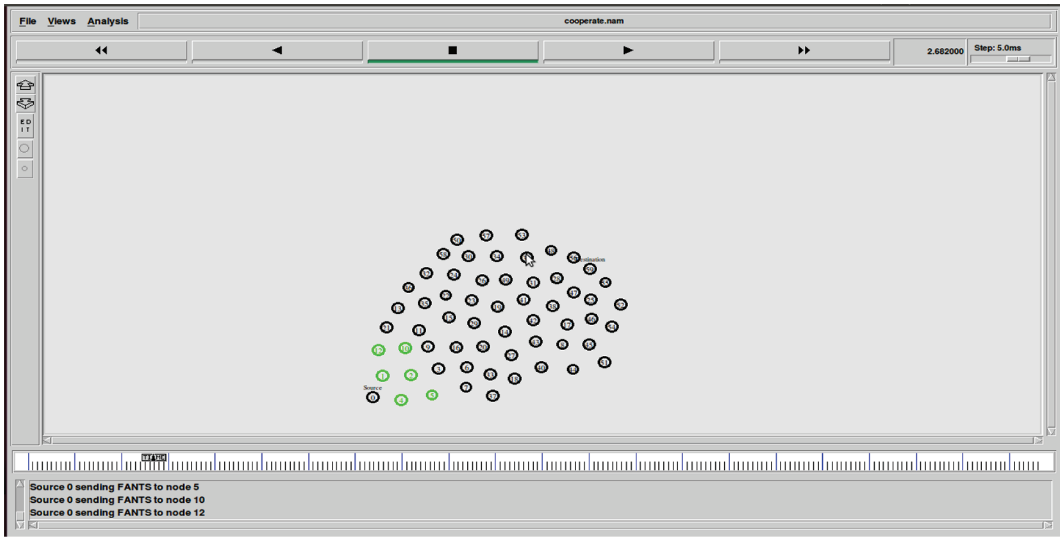

Figure 4: Shows the result of source node sharing the FANT among nodes with one hop distance

When the route requested packet arrives at destination 59, Backward Ant (BA) is generated with the goal of returning the route to the source, storing all nodes visited along the way, and updating the pheromone value, residual energy, and distance at both the intermediate and source, as shown in Fig. 5.

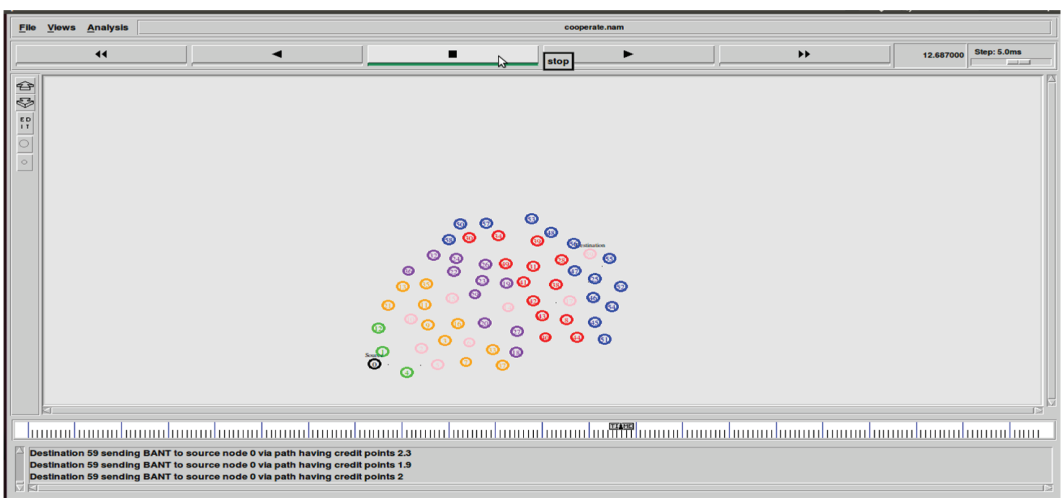

Figure 5: Shows the result of destination node 59 sharing BANT to source node 0 via path showing reward point on basis of pheromone, energy and distance

Fig. 6 shows the source node 0 delivers data to the destination node 59 via a path with greater reward points based on larger pheromone value, higher residual energy, and lesser distance. In the diagram shown, the destination node responded to source node 59–17–14–6–2–0.

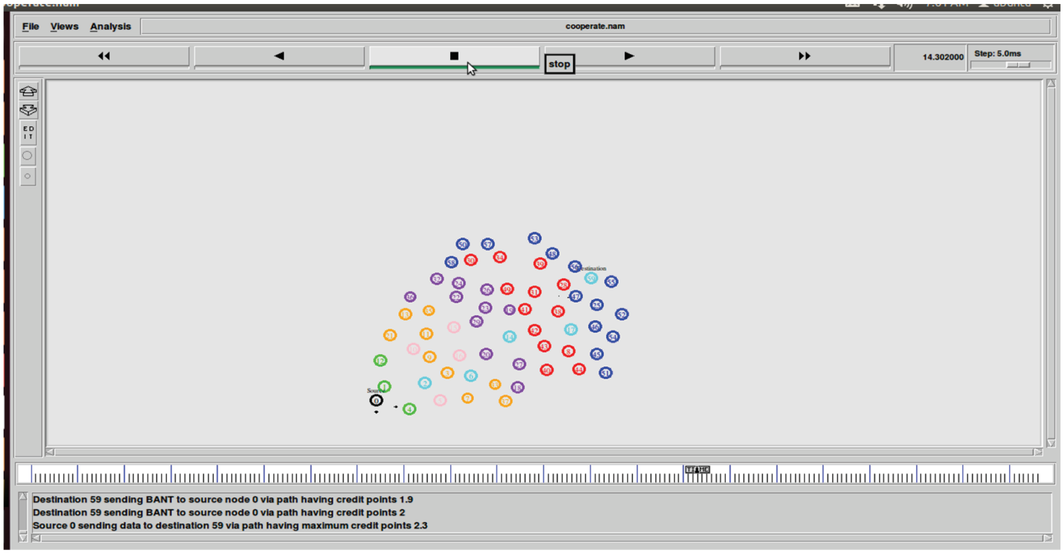

Figure 6: Shows the result source node 0 sending data to destination via path having higher reward points based on pheromone, energy and distance

On arrival at its destination, BA is created to communicate the path back to the source, recording all nodes visited, as well as modifying pheromone value, residual energy, distance, and mobility at both the intermediate and source 59, as shown in Fig. 7.

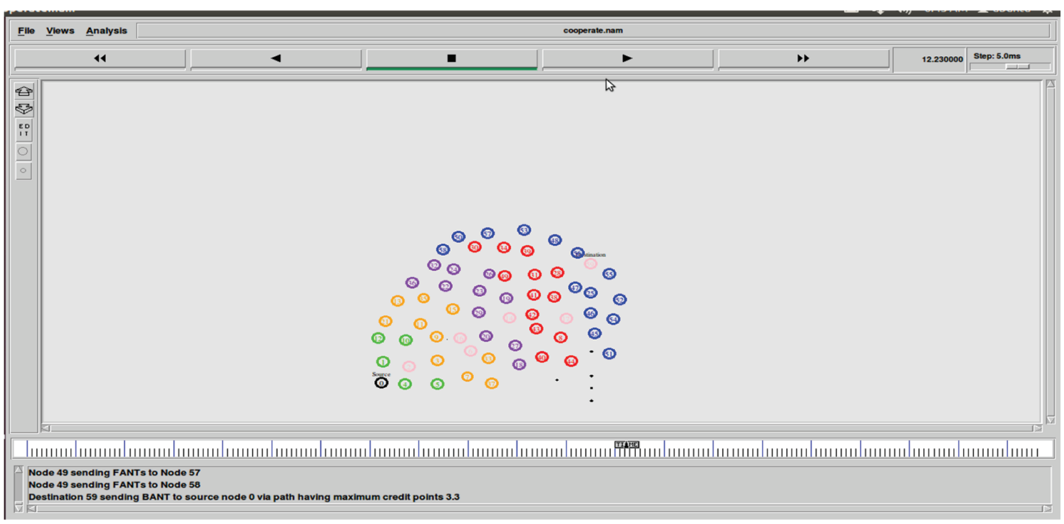

Figure 7: Shows the result of destination node 59 sending BANT to source node 0 via path showing reward point on basis of pheromone, energy, distance and mobility

The goodness value of all the paths through which the route request came will be computed by the destination node. The path that has the highest goodness value is chosen. The reward penalty-based system on pheromone, residual energy, distance, and mobility is used to calculate the highest goodness, as shown in Fig. 8.

Figure 8: Shows the result of a destination node transmitting BANT to a source node with the highest reward point based on pheromone, energy, distance and mobility

Fig. 9 shows that the source node 0 transmits data to destination 59 through the path with greater credit points based on large pheromone, highest residual energy, lowest distance, and fewer mobility nodes accessible in the network. In the diagram above, the destination node responded to the source through node 59–17–14–16–2–0.

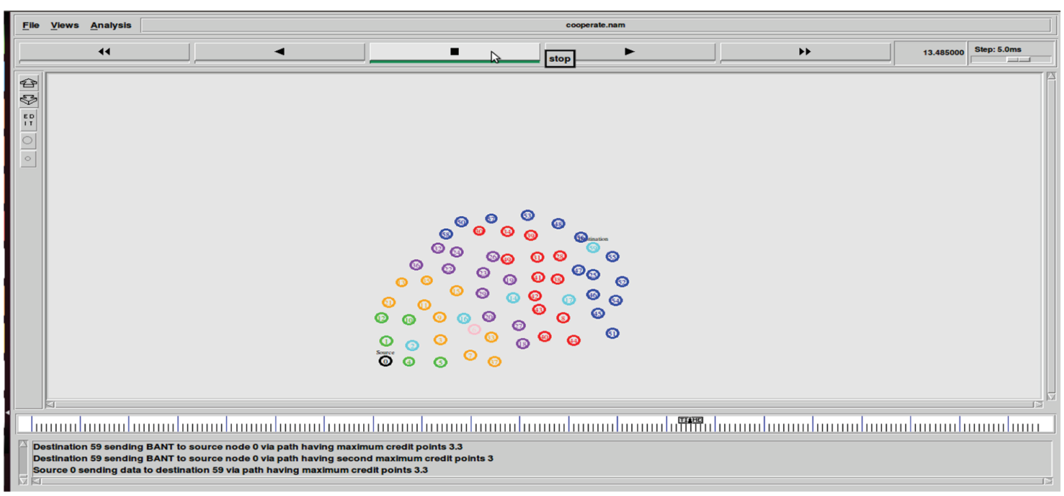

Figure 9: Shows the result source node 0 sending data to destination via path having higher reward points based on pheromone, energy, distance and mobility

6 Conclusion

Routing is one of the prime concerns in MANETs. Therefore, the main intent was to devise some approaches for optimal routing using the variables like residual energy, node mobility, as well as distance. The proposed algorithm is evaluated and simulated on NS2. Also, an approach based on a reward and penalty system has been introduced in this paper in which the proposed algorithms for optimal path are evaluated and tested. The proposed algorithms are assessed based on a variety of variables, like packet drop rate, delay, throughput, and residual energy. Here, the optimal path selection is made by the proposed algorithms for the optimal routing based on parameters like energy, distance, mobility and pheromone value. According to the research carried out, less link breakage occurred in the system when the route was built using the variables as stated. As a result, there were fewer packet losses, which improved the network's PDR as well as its bandwidth. Moreover, fewer control packets are delivered to the system to assist the linkages when network links are not routinely broken. Furthermore, energy efficiency was also achieved for the network by restricting the less energy nodes from taking part in the broadcasting process to form the routes.

7 Future Work

In the future, some ensemble learning techniques of machine learning will be utilized for the analysis of the proposed approach for better insights. Also, this paper utilized multi objective optimization techniques for the proposed approach. Moreover, the possibility of the implementation of the proposed approach in Flying Adhoc Networks (FANETs) will be explored in the future.

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