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PERFORMANCE ANALYSIS OF PARTICLE SWARM OPTIMIZATION AND DYNAMIC SOURCE ROUTING FOR PACKET ROUTE OPTIMIZATION IN MOBILE AD-HOC NETWORKS

Bhushan S. Chaudhari

Professor

Department of Information Technology,

Shri Vile Parle Kelawani Manda's Insitute of Technology, Dhule

Abstract: *Efficacy of routing in mobile ad-hoc networks has become a crucial part as a result of the enhanced use of mobile devices and the demand for self-managed networks. Most of the conventional routing protocols have their own limitations in providing secure and cost-effective services. Many researchers have proposed the use of swarm intelligence protocols for routing in MANET however none of the same provide the de-facto solution to issues related dynamic nature of MANET. A novel approach using particle swarm optimization (PSO) to provide a cost-effective solution is proposed in this paper. The experiment is performed using a network simulator tool NS2 and MATLAB. The routing performance of PSO is compared with a commonly used algorithm called dynamic source routing (DSR). This research clearly dictates that PSO is well suited to the dynamic nature of MANET and its performance is superior to DSR.*

Index Terms **- Ad-hoc network, Particle swarm optimization, Dynamic Source Routing, Quality of Service.**

I. INTRODUCTION

Invent of wireless technology has made our livelihood more progressive and productive. Unlike traditional structured networks, wireless networks don't require conventional media for communication. With the minimum cost of installation, computing nodes are able to communicate with each other in wireless networks. Move over, infrastructure-less networks have laid the foundation of fastest and cost-effective communication. Flexibility is one of the great advantages of the wireless network. To fulfill the needs of temporary scenarios ad-hoc networks are a great demand. Devices like laptops, smartphones, and tablet computers have changed our daily routines greatly

The characteristics of mobile ad-hoc networks make the QoS support a very complex process unlike in traditional networks [1]. First, the nodes in the ad-hoc wireless network have limited power capabilities and they are prone to failure due to the lack of battery power. Dynamic behavior of nodes like low signal quality or node failure leads to changes in topology as well. It may lead to frequent path breaks. Therefore, this research proposes a novel routing protocol using the Particle Swarm Optimization (PSO) algorithm to establish a path in the network that meets QOS requirements by considering the bandwidth conditions prior to the determination of path. The paper starts with the survey of ad-hoc network topologies and a brief discussion of PSO and DSR algorithms. Later, the proposed routing model using PSO and DSR is discussed. The paper concludes with MATLAB simulation results and guidelines for future research.

1.1 Ad-Hoc Network Topologies

MANET routing topologies are categorized based on node density, route transmission capacity, etc. Possible topology formations in ad-hoc networks are as follows[2]:

1. Static One Hop Topology

Hop refers to the number of nodes a packet travels on the route from source to destination. The static one-hop topology is formed as a result of all nodes in the radio range of another node. None of the nodes require an intermediator node for packet transfer. The nodes are bound to stay in the same network and cannot move on their own.

2. Static Multi-Hop Topology

The node positions in this kind of topology are too static with respect to movement. However, all nodes may not be in radio range of one another. Therefore, a packet may have to travel through intermediate nodes, called multiple hops. The phenomena of hidden and exposed nodes are possible. The identification of routes (routing) is required before the source node forwards packets to neighboring nodes.

3. Dynamic Multi-Hop Topology

Nodes are free to move within a network in this topology. This results in the dynamic nature of structure formation among nodes. Its dynamic nature requires continuous monitoring of routes, to ensure node connectivity[3].

4. Scatter Ad Hoc Topology

The meaning of scattering refers to the dynamism of nodes and network non-overlapping. The network does not interfere with each other. This type of evolved from Bluetooth connected devices. Heterogeneity of nodes leads to frequent route discovery.

Although all ad-hoc network topologies are overviewed above, the most significant topology suitable to the heterogeneity of nodes, scatter ad-hoc topology is chosen for experimentation of this research.

II. RELATED WORK

2.1 Particle Swarm Optimization

Swarm Intelligence is a discipline that deals with computation methods to solve complex problems by using methods inspired by the collective social behavior of relatively homogeneous swarms[4].

Particle Swarm Optimization (PSO) is a swarm-based stochastic optimization technique invented by James Kennedy and Russel Eberhart[5]. This algorithm is based on social behavior and movement dynamics of birds, insects, and fish. This technique is best suitable for continuous-variable problems. PSO is successfully been applied to structural optimization, neural technology, shape technology, etc. The major advantages of this heuristic technique are a simple implementation, scalability for designing variables, concurrent processing, efficient global search, etc.

While flying, birds (particles) adjust their directions and positions based on their own flying experience and flying experience of group members. Each of the particles attempts to reach the destination using this cumulative experience. Each particle keeps track of all fitness values achieved in all iterations. The optimum value is called pbest. The best value achieved by any neighboring particle in an individual iteration is called gbest. Particles keep on changing their directions based on pbest and gbest locations leading to the optimum location (destination). Each particle tries to modify its position using the following information:

own current location coordinates,
the difference between current location and pbest,
the difference between the current location and the gbest.

The new location (local minima) of any particle is calculated using following equation:

$$V_i^{k+1} = wV_i^k + c1 * rand1(\ldots) * (pbest_i - s_i^k) + c2\ rand2(\ldots) \times (gbest-sik) \ldots. \quad (1)$$

where,
vik : the relative trajectory of particle i at kth iteration,
w: particle’s weight
cj : weight constraint factor,
rand: random number value between 0 and 1 considering network constraints,
s_i^k : the current location coordinates of agent i at kth iteration,
$pbest_i$: best objective function value obtained by particle i,
gbest: best objective function value obtained by the group.

The following weighting function is usually utilized in (1)

w = wMax-[(wMax-wMin) x iter]/maxIter (2)

where,
wMax= weight of the particle initially,
wMin = weight of the particle finally,
maxIter = maximum iterations permitted,
iter = current iteration value

$s_i^k +1 = s_i^k + V_i^k+1$ (3)

The PSO algorithm has proved itself to be effective over other algorithms in several research areas[6].

2.2 Dynamic Source Routing

The Dynamic Source Routing (DSR) is an on-demand source routing protocol[7]. Each mobile node maintains identified routs in its route cache and keeps on updating till a new optimum route is discovered. This protocol works in two major parts named discovery of routes and maintenance of the route. If an optimum and unexpired route to a destination is available in its route cache, then the same is followed for transmission. Else, the discovery of a new route is initiated. The route request packet contains the fields such as source node address, destination node address, and unique identification number. Every intermediate node checks for route availability in its route cache. In case of non-availability, each intermediate node adds its own address to the route request packet and forwards it to the next neighboring node.

When the destination node receives a route request packet, a route reply packet is generated and the reverse route available in the route request packet is followed to reach the source node. Figure 2 presents the working of the DSR algorithm.

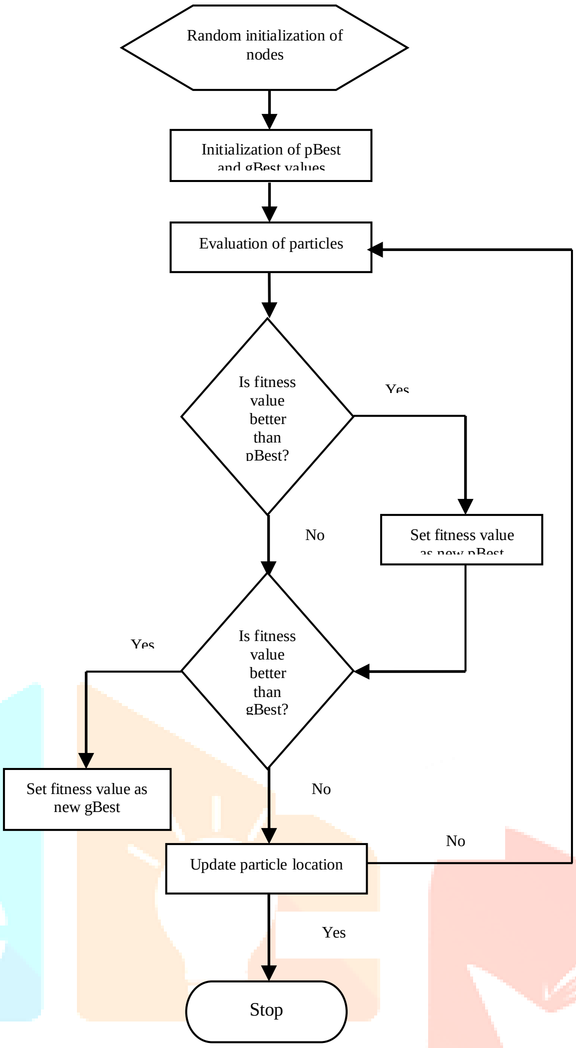

Figure 1: Working of PSO algorithm

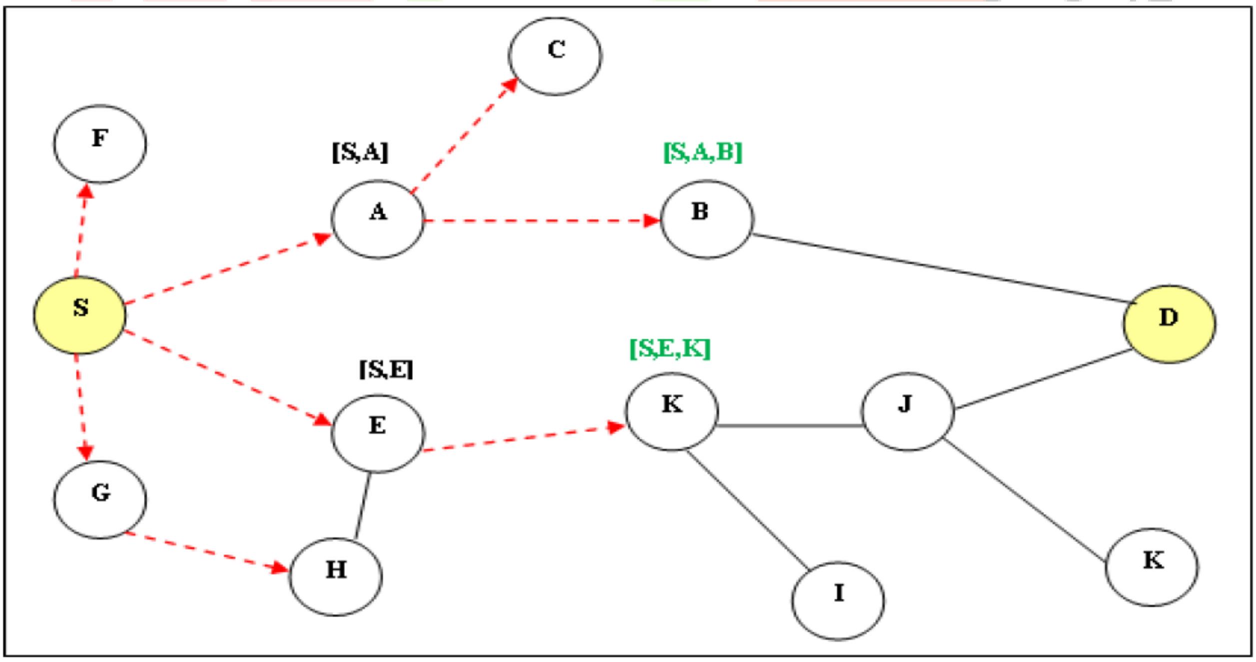

Figure 2: Working of DSR algorithm

III. METHODOLOGY

As the proposed work is a simulation-based project, in this project the geographical barriers which current networks may face are not considered. The mapping with the physical location of nodes is done with a graph having the X and Y-axis. Hence, we can describe the location of each node using x and y coordinates of node positions. It's the easiest approach to calculating the distance between two nodes. In an ad-hoc network, the node positions may not be fixed but, for the sake of simplicity, the node positions are randomly initialized and kept static to make an impact of scattered topology. It is very difficult to find bandwidth available at each node as there are many factors on which bandwidth is dependent. The random initialization of bandwidth is done before running the routing on the network. Once the node is hit in a route discovery, its bandwidth value is subtracted by the number of packets because of the route request/reply behavior of the DSR algorithm.

The number of nodes in an ad-hoc network may not be fixed and that's why the user is asked to enter the node value early in the execution. However, the simulation performs well if the number of nodes ranges from 25 to 50. The scaling of the network graph can be adjusted as the node value increases. The density of nodes is directly proportional to a number of routes. Unfortunately, the PSO algorithm does not provide actual target location for packet forwarding, instead, it provides a trajectory to target which may not be the exact position of the next neighbor node. Therefore, the nearest node to a directed position is considered as the next node to overcome this issue. This results in an increased value of hop count.

Step 1: MANET containing predefined node size is implemented. Node positions, bandwidth and battery energy of nodes are randomly initialized. The node position keeps on updating periodically.

Step 2: While finding next node itself, the fitness of node is well-taken care. Equations for finding next node are as follows:

$$V_i^{k+1} = [\mathrm{sik} * \sum_{n=1}^{n}(\mathrm{b1} + \mathrm{b2} + \cdots + \mathrm{bn})] + \mathrm{e1} * rand * (\mathrm{pbesti} - \mathrm{sik}) + \sum(\mathrm{e1} + \mathrm{e2} + \cdots + \mathrm{en}) * rand * (\mathrm{gbest} - \mathrm{sik}) \ldots \quad (4)$$

$$s_i^{k+1} = s_i^k + V_i^{k+1} \quad (5)$$

where,

v_i^k : the relative trajectory of particle i at k[th] iteration

b_i : bandwidth available at node i at k[th] iteration

e_i: energy available at node i at k[th] iteration

rand : a uniformly distributed random number between 0 and 1

s_i^k : the current location of agent i at k[th] iteration,

$pbest_i$: the location of the individual node at its personal best value of an objective function.

gbest : the position of any node in the group at its best objective function value

pbest and gbest values are calculated using the following fitness function F.

$$F_i = Min\ (Distance\ between\ node\ i\ and\ Destination\ Nodes) \quad (6)$$

Step 3: The node nearest to next node position calculated through equations 1 and 2, is considered as the next node.

Step 4: Out of neighboring nodes available for next hop, a node with the highest energy and bandwidth is chosen.

Step 5: The procedure is repeated till the destination node is reached.

Step 6: All intermediate nodes visited are tracked in the RREQ packet header. The reverse route is followed by sending the RREP packet.

Figure 3 explains route discovery using PSO. Node 'S' and 'D' represents source and destination nodes respectively. Dotted circles represent the radio range of respective nodes. Nodes C, G, and H are intermediate nodes on route S-C-G-H-D. These nodes are selected since they possess greater fitness levels in terms of energy and bandwidth.

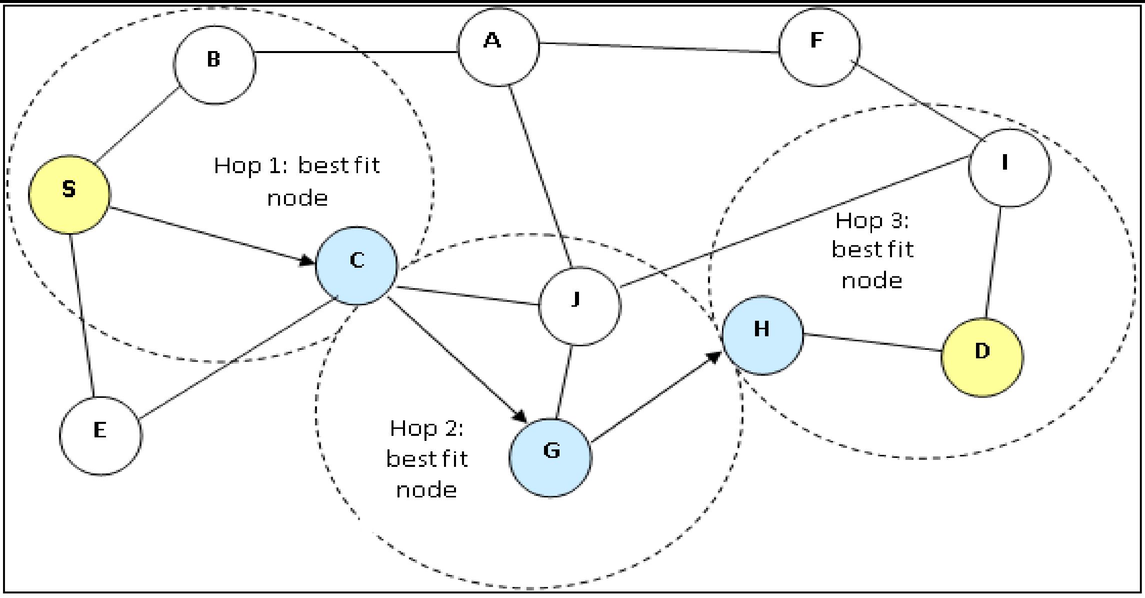

Figure 3: Route discovery using PSO

IV. Protocol performance parameters

To achieve effective routing in MANET, attribute selection is the most important part. Researchers have focused on attribute selection guidelines in depth[8].

4.1 Average End-to-End (ETE) Delay:

End-to-end delay (ETE) is the delay incurred in the transmission of a data packet from source and destination (received time minus sent time) [9]. As far as communication in MANET is concerned, the delay factor varies from node to node. The node receiving and transmission capabilities of nodes highly impact on ETE delay.

To calculate the average ETE delay, it is essential to consider all nodes on the transmission line. Considering the best route chosen by the routing algorithm, an average of ETE delay at each intermediate nodes between source and destination nodes need to be taken into consideration.

While calculating ETE delay at each node, three factors should be taken into consideration such as transmission delay, processing delay, and propagation delay. Considering there is no congestion in the network (queuing delay can be neglected) and there are N nodes on the selected route, ETE delay can be modeled as,

$$d_{end\text{-}end} = N[\, d_{trans} + d_{prop} + d_{proc}] \qquad (4)$$

where,

$d_{end\text{-}end}$= end-to-end delay

d_{trans}= transmission delay

d_{prop}= propagation delay

d_{proc}= processing delay

Also,

$$d_{trans}=L/R$$

where,

L= packet size,

R= transmission rate is R bits/sec

4.2 Packet Loss Ratio:

Failure of packet reception (partially or fully) results in packet loss. Factors such as errors in data transmission, network congestion, and buffer overflow and intrusive attacks result in packet loss. Maintaining a transmission window may reduce packet loss in communication. When the threshold of packets accumulated in the buffer at the sender node is reached, the flow of transmission should be slowed down. The threshold value depends on link capacity. Link capacity is measured in terms of the maximum transmission count of data packets.

Packet Loss Ratio (PLR) is the fraction of data packets dropped with respect to the total number of data packets transmitted[10]. Poor connection between two communicating nodes results in higher packet loss. Higher PLR usually results in a poor quality of service in wireless communication and lowering packet throughput.

4.3 Average Packet Throughput:

In general, the rate of successful packet transmission is called throughput for that particular communication route. The unit of packet throughput is bits per second or number of data packets per second. The rate of successful packet delivery varies from node to node varies for each node. Responsible factors affecting transmission channel throughput are node energy limitations, poorly configured system, the unreliable medium of communication, etc.

In an asynchronous environment such as MANET, the throughput of the nodes presents on route opted for data packet delivery is evaluated to calculate the throughput of the link. The average number of packets successfully received by all nodes on the optimal route per second is termed as average packet throughput [11][12].

4.4 Hop count

In MANET, when two communicating nodes are in radio range of each other then, it is peer to peer communication. However, due to the dynamic and ever-changing MANET environment, it's hardly possible for nodes to be in radio range of each other. In such a scenario, hopping becomes unavoidable for communication. Every intermediate node contributed for packet forwarding is counted as one hop [13]. A number of hops required to deliver packets from source to destination are one hop count. If there are n nodes on a route chosen for communication, then n-1 is the hop count.

4.5 Signal to Noise Ratio

Noise is any type of disruption with communicating links. MANET communication usually suffers from signal noise due to unpredictable wireless media. The reasons behind the noise in communication links are broken links, link outage, the poor transmission capacity of MANET node, etc. Signal to Noise ratio (SNR) is the level of signal strength relative to the noise level[13][14]. SNR is generally measured in decibels.

$$SNR = P_{Signal} \; / P_{Noise} \qquad (5)$$

Where,

P_{Signal} is the average signal power and,

P_{Noise} is an average noise power

Higher SNR is positive and results in the efficient delivery of data packets. High noise power leads to poor communication quality.

4.6 Data Rate available on the Route

Node dynamism often incorporates varying bandwidth at MANET nodes. Higher available bandwidth at different nodes collectively results in the improvement of the quality of transmission [15]. Bandwidth estimation of an individual node is based on the bandwidth availability of neighboring nodes, channel bandwidth, etc. Multipath routing produces different routes for communication between the source and destination nodes. In general, routes are obtained by flooding the 'Hello' packet in the network. Routing protocol should follow the route with a maximum available bandwidth for communication.

V. DISCUSSION AND SIMULATION RESULTS

Implementation in MATLAB 6.0 clearly shows that PSO finds optimum results than DSR and effective even in the case of limited bandwidth which is the major challenge for ad-hoc networks. Separate functions for PSO and DSR are implemented in this research. By providing values like a maximum number of nodes, the source node, and the destination node, it is possible to observe the shortest route discovery in the MATLAB window. Figures 4 and 5 show the results of the actual execution of DSR and PSO algorithms under a controlled environment.

Table 1 explains the optimum route length with varying node values. As the results are simulation-based, bandwidth considered here is a maximum number of connections a node can accommodate. It may happen that the route discovery may not reach the destination node. In such cases, the incomplete routes are not considered. Delays in the real networks are not considered in this project to maximize execution speed. However, by modifying the cost function, it is possible to introduce the delay factor as well. For the sake of convenience, only distance and bandwidth are considered in the cost function of this simulation. As per the desired conditions, other factors can also be considered. Since PSO is a heuristic technique, possibly it may not result in an optimum route identification at each iteration[16]. But in most of the conditions, it is better than algorithms in real use. With the purpose of comparing the performance of PSO, one more protocol called Dynamic Source Routing is implemented.

Table 1: Route discovery statistics

Node value	Method	No. of routes traced	Max BW	Min BW	Optimum route length
20	DSR	6	340	180	2.1643e+001
	PSO	10	920	100	1.0929e+001
30	DSR	21	720	230	2.3985e+001
	PSO	35	940	210	2.1584e+001
40	DSR	38	860	330	4.86475e+001
	PSO	56	1030	290	3.4582e+001

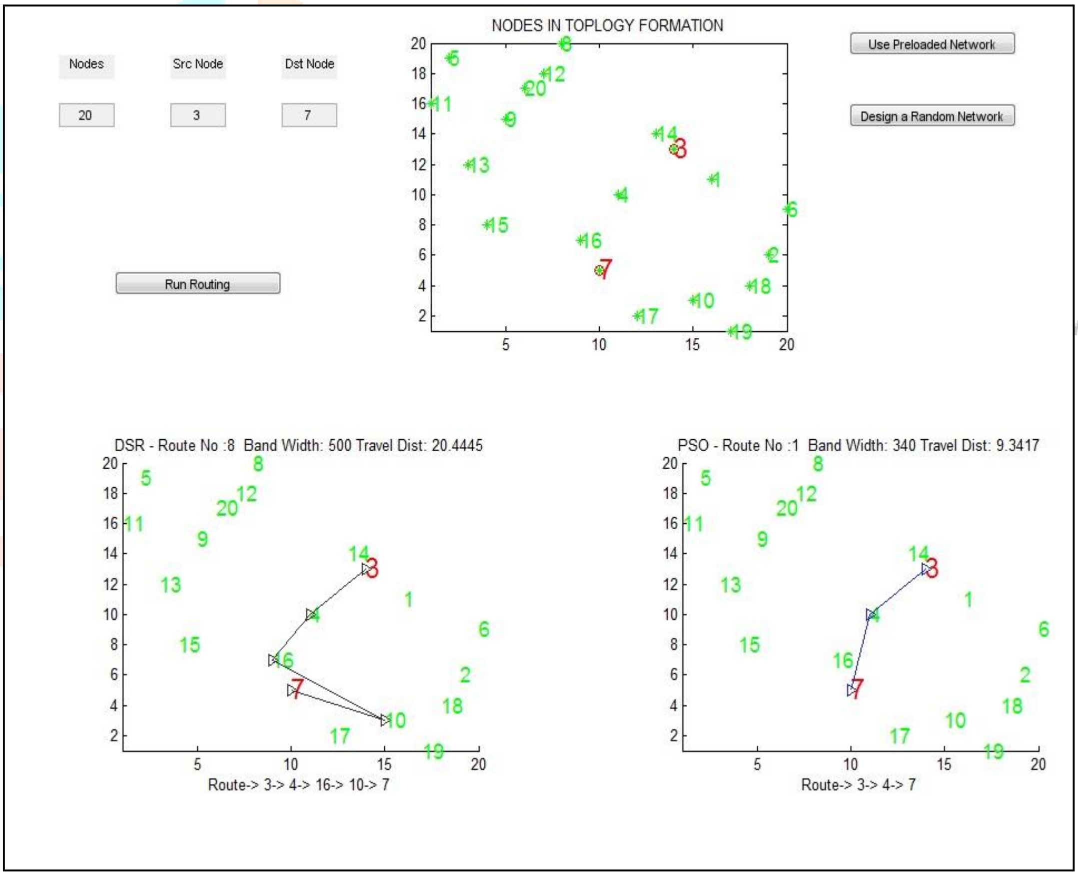

Figure 4: Simulation on shortest route discovery using DSR and PSO

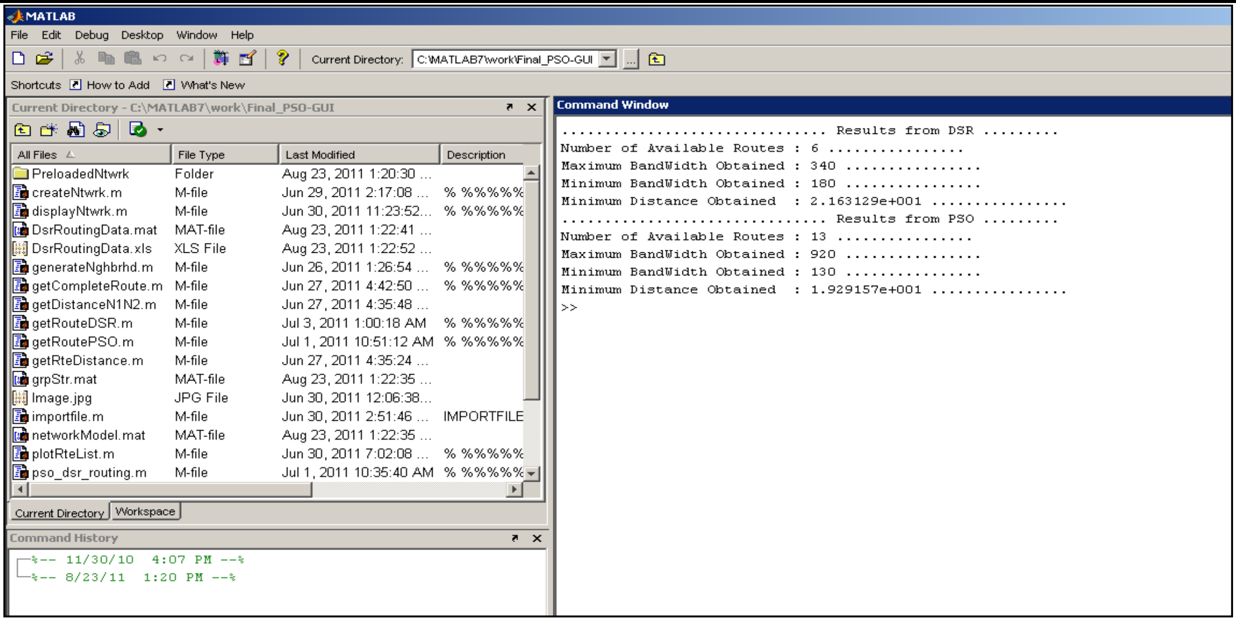

Figure 5: MATLAB command window with a summary of the shortest route discovery.

CONCLUSIONS & FUTURE SCOPE

Experimental results obtained clearly shows that routing using PSO is effective than DSR. For the sake of implementation, only a few parameters like bandwidth at each node involved in routing and distance between communicating nodes are considered in the formation of the objective function. To monitor the routing performance, average node density is considered. The respective geographical positions are randomly initialized. Each algorithm is deployed as a routing protocol in the pre-established ad-hoc network. The simulation results, when running in NS2 for DSR and PSO indicate that route optimization may be achieved using PSO effectively than DSR. Routes obtained using PSO are stable than obtained using DSR.

More research is required on the effective utilization of PSO parameters like individuality and sociality. Binary and Quantum PSO may serve better in the dynamic environment of the ad-hoc network.

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