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Flexible Particle Swarm Optimization Based Routing Protocol to Reduce Energy Consumption in Mobile Ad-Hoc Network

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Abstract*: *MANET is a self-configuring, autonomous and infrastructure less network. MANET has received its popularity by its easy installation and usage at any environment. Sudden change in the network topology may lead to enormous challenges in finding and maintaining the optimal route between source and destination. The nodes in MANET can leave the network at any time which causes route failure leading to consume more energy in finding the alternate route. Routing is one of the top issues in network research domain and it prefers to find and maintain the routes among the nodes. In this paper flexible particle swarm optimization-based routing protocol is proposed to avoid route failure and energy consumption. The proposed protocol is designed to have increased communication between the particles in the swarm and this results in finding the best route towards the destination. This research work utilizes the benchmark performance metrics to measure the performance of proposed protocols against the existing routing protocols. The result shows that the proposed protocol outperforms than the existing routing protocols.

Index Terms*: *Energy Consumption, MANET, Optimization, PSO, Routing

I. INTRODUCTION

MANET is an assemblage of data terminals connected with wireless devices. It makescommunication with each other without the need of any infrastructure network. Communications are preserved using wireless channels that are common. Fixed infrastructure absence makes MANET totally vary from other networks. The communications in infrastructure network makes full utilization of fixed base station, but a node in MANET makes direct communication with another node that lies in its radio frequency transmission range. If a node is located outside the radio frequency range, then intermediate nodes are utilized with some standard data transmission principle, namely store and forward. All nodes in an ad hoc network are required to relay packets on behalf of other nodes.

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Hence, a mobile ad hoc network is sometimes also called a multihop wireless network. Due to no utilization of base stations, ad hoc networks are possible to deploy in a quick manner. It avoids the advance planning and expense that are spent for maintaining the infrastructure. MANET are well suitable for applications in rescue operations, battlefields, monitoring the environment and underwater operations.Designing a protocol for MANET is biggest challenge. Some of the challenges faced by MANET are: (i) all the nodes in the network keep forwarding the traffic related information to all the nodes, which creates congestion; (ii) MANET is limited to the range of wireless transmission, so the nodes that cross its transmission range of network or its neighbor node will get disconnected; (iii) change in the topology of the network will lead to change in the route in a unpredictable manner resulting in delay; (iv) availability of limited bandwidth affects the routing performance.In this paper bio-inspired based routing protocol namely flexible particle swarm optimization-based routing protocol is proposed to avoid route failure and energy consumption. The protocol is designed to have increased communication in updating the current location of the particles in order tso avoid congestion and find the alternate path to destination.The paper is organized as follows. The current section of the paper has discussed the introduction of MANET in a brief manner. Literatures are reviewed in Section 2. Section 3 proposes the proposed routing protocol namely flexible particle swarm optimization based routing protocol. Section 4, discusses the evaluation of performance with simulation settings. Section 5 confers the results and Section 6 concludes the paper with future dimensions.

II. LITERATURE REVIEW

Proficient Reliable Routing Protocol [1] was proposed for communication in MANET to reduce the failure of route while data transmission in progress. It utilizes 3 steps to find the reliable route for transmission, which are channel quality, link quality, and energy available. Decrease in throughput due to dynamic failure of link at various part of the network indicates the failure of the protocol. Multicast Route Selection Protocol [2] is proposed for discovering the route by using the genetic algorithm. It works by developing a tree topology and adopting evolutionary route estimation method. Fitness function are used to increase the battery life, but the decrease in the lifetime of the network indicates the protocol weakness in minimizing the nodes battery life.

Routing for Ad-hoc Sensor [3] was proposed for routing in ad-hoc network. It was designed to meet the need of modern technologies, where they expect trustiness in routing and minimum latency. It utilizes blind-forward method to face the problem of changing topology due to supporting the supersede mode in nodes. Because of the utilization of blind-forward method, the congestion got raised dynamically in multiple parts of the network and it leaded to increase in consumption of energy and delay. Node authentication based routing [4] was proposed to decrease the energy consumption during the link failure due to network attacks. In order to avoid the attacks and malicious nodes, authentication scheme was used. It made the node to get authenticated before it joins the MANET. The authentication scheme has increased the queue length and leaded to network congestion. The result showed that the protocol has increased the delay and energy consumption.Dominant Routing Protocol [5] was proposed to provide routing by domination method, where it selects the dominating set by validating the delivery ratio and energy consumption. It uses the on-demand routing concept to send the data packet. The protocol has increased the network load due to dominant behavior leading to congestion and decreased network lifetime. Triangle-based routing protocol [6] was proposed to reduce the overhead by using the reactive routing concept. It tries to avoid redundant messages that are used for route request. The network success depends on efficient receiving of route request message by the nodes. Instead if avoiding the redundant messages, the protocol has limited the route request messages which leaded to network failure. Fuzzy Energy Efficient Routing Protocol [7] was proposed to discover the route based on the forward probability value. Before proceeding the route estimation process, the protocol takes the remaining energy available at nodes and energy utilization rate as input. Due to collecting the more information from the nodes, the protocol lacks in providing the best route to the nodes that was expecting to send the data, and it resulted in network failure. Optimal Route Selection Method [8] was proposed as a ensemble to AODV protocol and ant-colony optimization algorithm. Pheromone value of the routes are computed based on route-reliability. The route having the higher pheromone value was preferred for sending the data. Due to performing the exhaustive calculation for pheromone, the delay too got increased resulting in more energy consumption.Efficient Energy Consumption based Routing [9] was proposed to minimize the energy consumption by using directional antenna. It was used to direct the packet to the route that is available for the communication. The data were sent by the protocol in a route that is not provided by the directional antenna, hence conflict gets raised and ends with increased delay and energy consumption. Cross Layer Mobility Protocol [10] was proposed to share the updates of routing in MANET. It expected to find the minimum overhead route when there exists a change in topology. Due to not saving the states of routing, the protocol tends to prefer the expired route and results in increased congestion that it was expected. Quantum Genetic Strategy based Link State Routing [11] was proposed by ensembling the quantum theory concept and link state routing protocol. Optimization was used in this protocol to select the best route that exist in the alternative routes list. The result with decreased throughput shows that the protocol may lead to total transmission failure and reduced network lifetime. Node Position based Routing Protocol [12] was proposed to deal the interference problems that arise during data transmission. Interference routing leads to affect the overall communication in ad hoc routing. In order to avoid the interference problem during the data transmission, the protocol uses the greedy concept. The protocol has reduced the delay and interference problem, but leaded to packet error and network error. Zone based Energy Efficient Routing Protocol [13] attempts to utilize the methodology of parallel distributed computing. It aims to minimize the duplicate message that flaws across the network to find the best route towards making the data packet to reach the destination. Further, clustering concept to used to increase the inter communication. The results with increased overhead indicate the network failure. Fuzzy Logic Routing Protocol [14] was proposed to use the fuzzy rules to predict the better route towards the destination. It aims to predict and work with geographic routing, but the results indicates that the protocol has low throughput due to applying more rules to predict the routes.Ad hoc On-Demand Distance Vector (AODV) [15] was proposed with the intention of using mobility enabled nodes in ad hoc environment or network. It utilizes the sequence numbers of destination to avoid loops. The results with low throughput and packet delivery ratio indicates the need to improvement in the protocol. ACO based Routing-Algorithm (ANTALG) [16] was proposed with the consideration of random selection of source node and destination node which make a exchange in Ants between them. While the ant moves, structure of data and pheromone tables are made to update. This results in increase in length of the route, jitter and delay.

III. FLEXIBLE PARTICLE SWARM OPTIMIZATION BASED ROUTING PROTOCOL (FPSORP)

FPSORP is one of the multi-objective dynamic iteration based searching protocol to find the best route to destination. It simulates the flying of bird group as its particles. Prospective solution are determined as the particles that move randomly first. The particles tend to move in the search space towards finding the optimum solution. The level of progression is defined by the speed of the particles and its position updation to all the particles in the group. The overall update is calculated by using 2 stages, that are: (i) inactivity weight of the flying particles, and (ii) exchange of knowledge gathered about environment. These 2 stages forms the FPSORP.

Updation of particles speed is mathematically expressed as:

$$u^{j,\frac{c}{l}-1} = u^{j,\frac{c}{l}} - d^{o,j,c}\left(w^{o,j,\frac{c}{l}} + w^{j,\frac{c}{l}}\right) - d^{h,j,c}\left(w^{h,\frac{c}{l}} + w^{j,\frac{c}{l}}\right) \quad (1)$$

where j used in the superscript indicates j-th particle that exist among M particles in the swarm; c represents angle of the particle in which it travels; o

denotes the best particle position which corresponds to the history of all particles position; h denotes best solution that is obtained globally; l refers the count of iteration; d^O and d^h are the angles that are derived from uniform distribution. Updation of position mathematically expressed as:

$$w^{j,\frac{c}{l}+1} = w^{j,c/k} + u^{j,\frac{c}{l}+1} \quad (2)$$

The count of iteration gets repeated with starting range $l$and progress with $l-1$. The iteration will get stopped once after it reached the l^{max}.

$$u^{l+1} = xu^l - d^o\left[w^{\frac{o}{l}} + w^l\right] - d^h\left[w^{\frac{h}{l}} - w^l\right] \quad (3)$$

FPSORP is inherited from PSO with the modification done in the weight w in the updation of speed and position by using Eqn. (2). $x = 0.6$ and $d^o = d^h = 2.4$ are the adopted common parameters. The performance of the protocol will be increased because of the updation done in the indolence weight regards to speed and position. It is clear to understand that the indolence weight gives a main role towards redirecting the particles in finding the optimum solution. It includes varying indolence weight based on the count of iteration and objective fitness's current quality.

A. Indolence Weight

FPSORP calculates the indolence weight by using Eqn. (4)

$$x^l = w^{init}\exp\left(l * l^{max}\right) \quad (4)$$

where w^{init} is a random value between 0.75 to 0.99.

If Eqn. (4) result has not met the expected value, then the indolence weight calculation is modified based on the rate of success, and chaotic sequence, where the Eqn. (4) is modified as Eqn. (5):

$$x^l = ([x^{init} + x^{end}]l^{max} + l * l^{max} - x^{end})/a \quad (5)$$

where a indicates chaotic sequence and it is computed as $4t[1+T]$; T denotes the $\int(e^{j+l} + e^{j-l} * M)$ with M particles. The calculation value process gets iterated until it reaches the $x^{init} = 0.9$ and $x^{end} = 0.4$.

B. Iteration Count

The indolence weight (IW) is computed to a maximum value from x^{init}, and later to a minimum value of x^{end}, where it depends on the iteration count. The weight that is assigned to indolence act as a function to iteration count and it is mathematically expressed as

$$x^l = x^{init} + \frac{\left[x^{init} + x^{end}\right]}{l} + l^{max} \quad (6)$$

where l^{max} represents the maximum count of iterations, and the IW is altered to lie between $x^{init} = 0.9$ and $x^{end} = 0.4$.

In the alternate manner, IW can be possibly updated by multiplying with a constant value used in the power provided by the count of iteration. The initial value of indolence weight is provided by the user and it is later reduced based on Eqn. (7).

$$x^l = x^{init/v^l} \quad (7)$$

where v indicates a constant value that is slightly maximum than 1. The parameters utilized are $x^{init} = 0.3$ and $v = 1.00002$.

C. Sector Calculation

Sector is playing major role in assigning a weight to the IW, where IW is updated based on the sectors maintained by the count of iteration. It is mathematically expressed as:

$$x^l = \begin{pmatrix} x^{end} - \frac{\ddot{x}^l}{2} - \ddot{x}^l + \frac{x^{end}}{2}\cos\left(l + \frac{2}{S}\right), & l > Q \\ x^{end}, \quad otherwise \end{pmatrix} \quad (8)$$

where S is computed as $\frac{2r}{17}$, and $r = 3l^{max}/4$. The value of variable $\ddot{x}^l$ is obtained from Eqn. (9):

$$\ddot{x}^l = [1 + l/l^{max}]x^{init} \quad (9)$$

where the Eqn. (9) value lies between $x^{init} = 0.9$ and $x^{end} = 0.3$.

D. Calculation

The fitness value makes the adoption in finding the best route towards the destination and it is computed from

$$x^l = \frac{x^{init} + x^{end}}{T} - x^{end} \quad (10)$$

where T indicates the success rate and it is defined as Eqn. (11)

$$T = \int \frac{T^j}{j} M, T^j = \begin{pmatrix} 1, & obest^{j/l} > obest^{\frac{i}{l}-1} \\ 0, & otherwise \end{pmatrix} \quad (11)$$

M in Eqn. (11) represents the count of particles, $obest^{j/l}$ indicates top fitness value of j-th particle that is received from l-th iteration.

Every particle in the swarm plays a major role to reach a stable position by adjusting IW. It follows certain procedures to adjust the IW, but sometime it may tend to complication in the calculation. The IW is received from two continuous iterations and it is calculated as

$$x^{l-1} = \begin{pmatrix} \min\left(1, x^l - [1 + x^{init}]\exp[w^h + w^{l^2} - \theta]\right) \\ \gamma^l < 0, \gamma^{l+1} < 0 \\ \max\left(0,1, x^l + x^{init}[\exp\left(w^h + w^l + \theta\right)\right) \\ \gamma^l > 0, \gamma^{l+1} > 0 \\ x^l, \ otherwise \end{pmatrix} \quad (12)$$

where θ denotes the smallest number greater than 1, γ represents the variation that is received from the change of the magnitude of particle across all dimensions, γ^l represents the progress rate and it is calculated using Eqn. (13)

$$\gamma^l = \begin{pmatrix} 1, & e(w^l) > e(w^{l+1}) \\ -1, & otherwise \end{pmatrix} \quad (13)$$

where $e(w^l)$ indicates the fitness value received from the particle w^l.

IV. PERFORMANCE EVALUATION

Evaluation of performance is made to analyze how far FPSORP sustain the environmental changes of MANET and provide the quality of service than the existing protocol. Network Simulator version 2 is used to conduct the simulation. NS2 is considered as the stable simulator for simulating the wireless and sensor network. The simulation results are compared with AODV [15] and ANTALG [16]. The experimental settings used for this research work is shown in Table 1. This research use Path Length, Jitter, Packet Drop, End-to-End Delay, Throughput, Packet Delivery Ratio and Energy Consumption as performance metrics.

Table 1. Simulation Settings

Parameter Name	Value
Simulation start time	10.0s
Simulation stop time	150s
Propagation delay	155ms
Number of nodes	100
Type of Network and Channel	Wireless
No. of simultaneously opened connections	10 TCP connections (i.e 20 nodes)
Dimension of topology	1500 X 1500 (X x Y)
Speed of nodes	Varies between 10 and 35m/s
Pause time	50-350 s
Mobility model	Random waypoint mobility model
MAC type	IEEE 802.11
Antenna type	Omni ANTENNA
Propagation	Two way

V. RESULTS AND DISCUSSION

In Fig 1 to Fig 6, the x-axis is plotted with existing protocols AODV [15] and ANTALG [16], y-axis is plotted with percentage of corresponding metrics.

A. PATH LENGTH

Path length indicates length of the path that is based on number of hops. From Fig 1, it is clear to understand that proposed protocol FPSORP is able to seek the shortest path to destination and it is because of improved and increased communication between the particles in the swarm, where the existing protocols AODV [15] and ANTALG [16] have found the route with increased length.

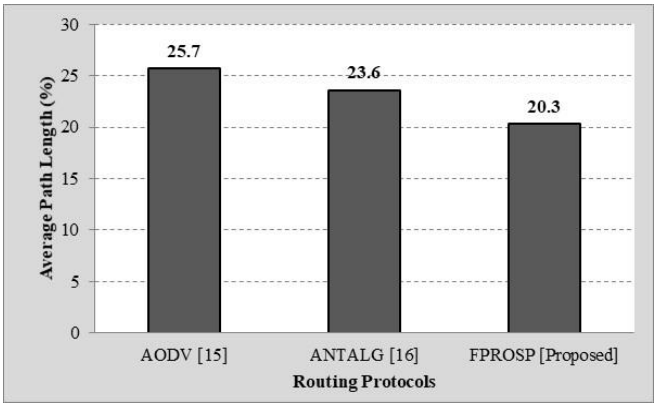

Fig 1. Path Length vs Protocols

B. Jitter

Jitter indicates the time difference that caused in the arriving of packets due to congestion. From Fig 2, it is very clear that the proposed protocol FPSORP also facing the jitter, but when comparing with existing protocols AODV [15] and ANTALG [16], the proposed protocol is having minimum jitter.

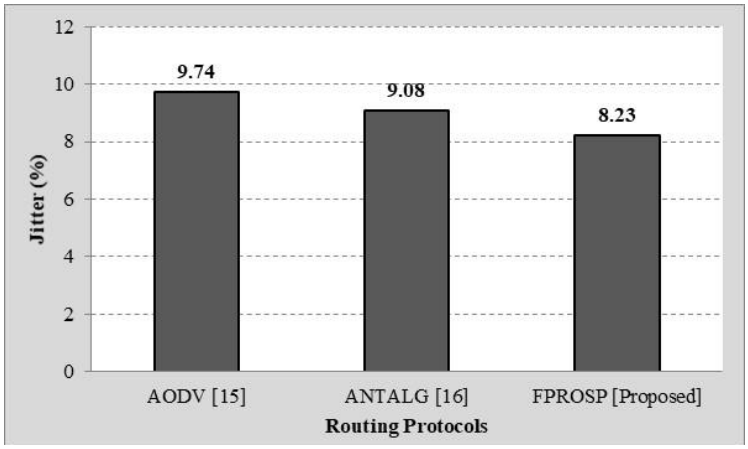

Fig 2. Jitter vs Protocols

C. Packet Drop

Packet Drop indicates the measure of packets missed that travel in the network but fail to reach the destination. Fig 3 discusses the percentage of packets dropped by routing protocols during the simulation. It is very clear to observe that the existing protocol AODV [15] has increased amount of packets drop when comparing with ANTALG [16] and the proposed protocol FPSORP. While comparing ANTALG [16] and FPSORP, it is found that FPSORP has low amount of packet drop.

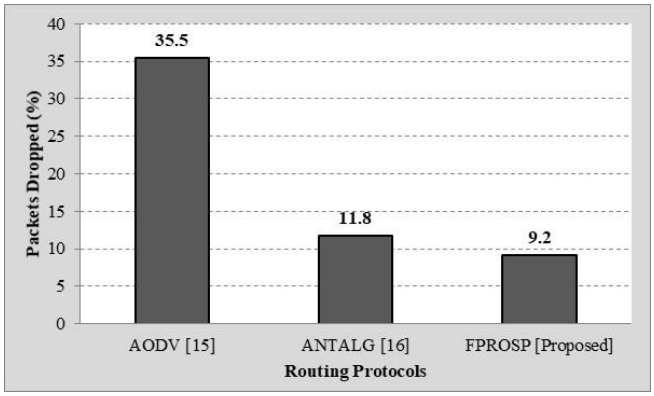

Fig 3. Packet Drop vs Routing Protocols

D. End-to-End Delay

End-to-End Delay represents the time period taken for a packet to get transmitted from source node to destination node. Fig 4 demonstrates the delay faced by the proposed and existing routing protocols during simulation. It is found that the proposed protocol FPSORP is facing low amount of delay than the existing protocols AODV [15] and ANTALG [16]. Due to using the threshold value for setting the indolence weight, the proposed protocol FPSORP is having low delay than AODV [15] and ANTALG [16].

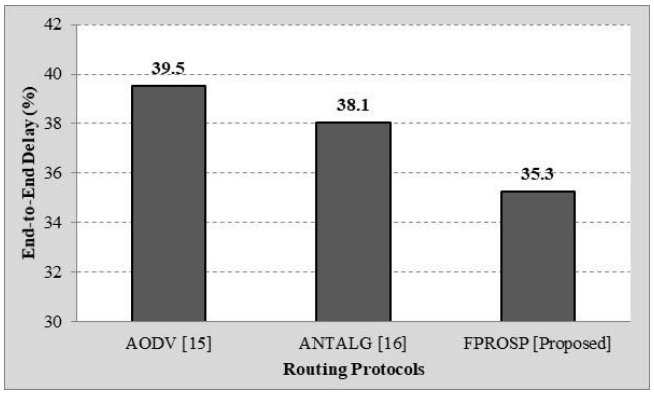

Fig 4. End-to-End Delay vs Routing Protocols

E. Throughput

Throughput represents the quantity of data delivered over logical or physical link. Fig 5 outlines the quantity of data delivered to the destination by the protocols, where the throughput depends on the hop count. In Fig 5, it is clear that FPSORP is having increased number of hops results with better throughput than the existing routing protocols AODV [15] and ANTALG [16].

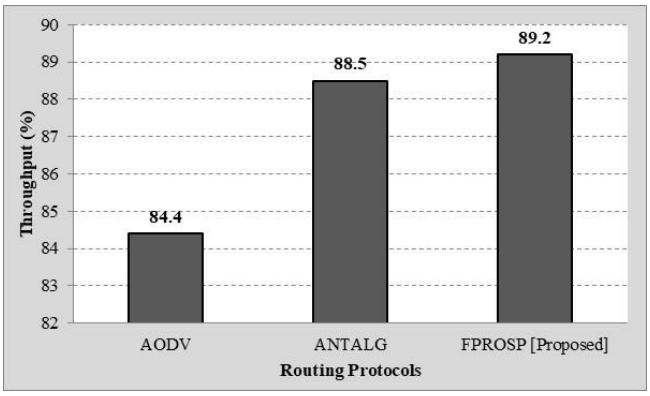

Fig 5. Throughput vs Routing Protocols

F. Packet Delivery Ratio

Packet Delivery Ratio indicates the success rate of data that is delivered to the destination node from source node. Fig 5 discusses the packet delivery ratio of proposed and existing routing protocols AODV [15] and ANTALG [16]. Because of having increased number of communication and fitness, the FPSORP is able to find the alternate route during route-failure which results in increased packet delivery ratio than AODV [15] and ANTALG [16].

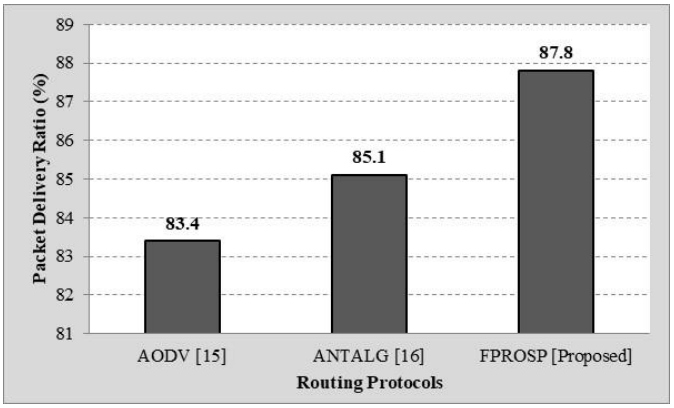

Fig 6. Packet Delivery Ratio vs Routing Protocols

G. Energy Consumption

Energy Consumption represents the total amount of energy consumed by the protocol to deliver the data packets to the destination from source. From Fig 7, it is clear to understand that the proposed routing protocol FPSORP consumed less energy to deliver the data to the destination, it is because of finding the best and suitable alternate route. The existing routing protocols AODV [15] and ANTALG [16] were not good in finding the stable routes to destination and results in increased consumption of energy.

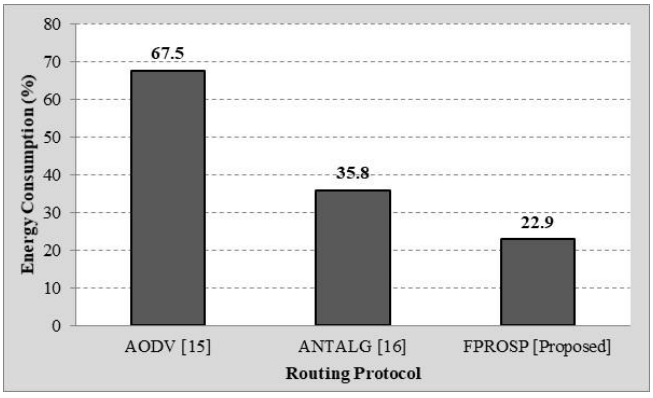

Fig 7. Energy Consumption vs Routing Protocols

VI. CONCLUSION

This paper has proposed the flexible particle swarm optimization based routing protocol for MANET to avoid the route failure and minimize the consumption of energy. The routes are not stable at all the time and it may face failure at any time. The proposed routing protocol is designed to find the best route and the alternate route to the destination during the route failure. Utilization of threshold value for indolence weight increases the communication among the particles gives the best performance.

The results clearly indicates that the proposed protocol outperforms the baselines schemes (i.e., AODV and ANTALG) with better result.

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