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A trust-based mechanism in multipath routing using Biogeography-Shun Optimization

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Summary

In mobile ad hoc network, a group of mobile nodes interconnect with each other in an ad hoc manner without any centralized administration. Various applications are based on integrating mobile ad hoc network and cloud computing to enhance the processing and storing of mobile nodes. Cloud service providers provide mobile ad hoc network users access to applications and other mobile ad hoc network users. Implementing security mechanism for ad hoc routing can be a daunting task owing it its unique network traits. Blackhole attack found in the mobile ad hoc network takes place when malicious nodes attract data packets using a fresh destination route and drop the packets. In this work, a trust-based routing that has a probability of a new packet forwarding is proposed to mitigate blackhole attacks. The ad hoc on-demand multipath distance vector routing protocol is used in this work, which is based on the trust model that measures the trust of nodes and composes a decision, respectively. A novel optimization technique that has its basis in the Biogeography-Shun Optimization algorithm is suggested for enhancing the multipath routing. Simulations demonstrate that the proposed method attains better performance by enhancing lifetime of network and packet delivery ratio and reducing end-to-end delay.

KEYWORDS

biogeography-based optimization, cloud computing, mobile ad hoc network, security, trust

1 | INTRODUCTION

Cloud computing offers on-demand network access in a convenient manner to a pooled set of computing resources such as servers, applications, or networks, which can be quickly set up with little effort or interaction from the service providers. Cloud computing is a paradigm that offers users with various capabilities for storing as well as processing their data in third-party data centers. The efficacy of the resources that are shared dynamically based on demand is optimized.[1]

Three core administration models are presented to customers: Software as a Service, Platform as a Service, and Infrastructure as a Service. Software as a Service primary target is end users who require the particular software in their day-to-day life. Platform as a Service targets application developers who require platforms for the development of various applications. Apart from these, infrastructure can also be made efficient and power-saving through cloud computing. A method to improve the capability of smart devices is to utilize cloud-based services in mobile ad hoc network modeling for device-to-device communications. Smart device users can utilize cloud services for discovering their devices and processing all kinds of media such as videos, images, and audio.[2]

The mobile ad hoc network is a mobile node compilation linked through wireless links that form a network without infrastructure or a central administrator. Mobile ad hoc network is widely used in data acquisition, emergency, search rescue, and the military. The network topology can change in a dynamic manner owing to the fact that the wireless mobile nodes can move in an arbitrary manner. Mobile nodes can act as either the sender, the receiver, or the intermediate router, and every node has limited power that keeps reducing.[3] The primary traits of the mobile ad hoc network are it operates without any central coordinator, which can be deployable in a rapid manner with multihop radio communication, frequent breakage of link, and constraint resources such as the lifetime of the batter, bandwidth, and computing power. Thus, the challenges in the mobile ad hoc network are that it needs to be distributed fully and adaptive to frequent changes in topology with maintenance and computation, loop-free route which is optimal with minimal collision.[4]

The cloud mobile ad hoc network mobility model integrates both cloud computing as well as mobile ad hoc network technologies. Mobile ad hoc network functionality depends on node mobility as well as connectivity, not to mention storage and energy efficiency. Cloud service providers typically retain the network infrastructure, storage, as well as applications which support flexibility, scalability, as well as efficiency.[5] Current advancements encourage mobile users to utilize the advantages of various new applications including mobile gaming and mobile learning. For fulfilling the requisites of different applications, the kinds of platforms for augmenting the resources of power-restricted mobile devices are remove cloud, server-based cloudlet, as well as mobile ad hoc cloud.[1]

Ad hoc network routing protocols are categorized as proactive or table-driven and reactive routing. Every node will keep the data of the other nodes in the network. It is retained in the routing table and updated when changes take place. Some periodic exchanges among topology data are presented ensuing in large overheads of routing. If not, in a routing protocol that is reactive, a node will not have to keep a routing table. If data have to be transmitted, it will begin the route discovery procedure to find the paths.

The multipath routing method attains many paths between the pairs of source and destination. Multiple routes are available among them like the higher bandwidth utilization, an end-to-end delay that is lower, high network life, and higher throughput. This can bring down the congestion of network and protects against the failure of routes. The process of path discovery for multipath routings normally selects disjoint paths that carry forward the actual traffic between both source and destination. There are two different types of multipaths. The mobile ad hoc network multipath routing protocols can compute different paths that are between the pair of nodes sending and receiving data in a single attempt. For route discovery, a process begins at the time of path failure between the source and destination.

Ad Hoc On-Demand Distance Vector Routing protocols are grounded in reactive techniques, and the messages used are the Route Request, Route Reply, as well as the Route Error. The destination sequence numbers are utilized to make sure that there was a loop free every time. In Ad Hoc On-Demand Distance Vector Routing, all source nodes will find a new path by flooding of the Route Request that has a ring expansion with a path to the destination through the Route Reply. Ad Hoc On-Demand Multipath Distance Vector Routing is used to achieve multipath routing with various routes. The static route method could not manage the dynamic changes in network leading to severe traffic congestion.[6]

Trust is a very crucial concept in network security and is considered as a measure among the entities and the nodes that are part of such network activities. The trust concept will be the same, and the trust people will be helpful as well. The main purpose behind developing such notions of trust in the ad hoc network was the provision of heuristics for security. Malicious or faulty nodes will be detected and further removed using minimal overheads. The three descriptions of trust are[7] as follows:

- Trust is a subjective probability for a single node performing an action based on its welfare (trustor, trustee).
- Direct trust is defined as the belief of a node in a particular interaction which consists of direct experience.
- Recommendation trust is stated as the entity that trusts another entity to be trustworthy owing to all recommendations made by the other entities.

For the routing problems found in the mobile ad hoc network,[8] in case of not having an optimal path to communicate information from the source to the destination, there may be problems like high consumption of energy and high transmission delay that take place. So, there is a need for an optimization algorithm in routing for solving the problem.

In the case of a network that is densely populated, the problem of routing optimization includes a combinatorial optimization. This proved to be a problem that was Nondeterministic Polynomial-hard having a computational effort that grew exponentially along with the number of nodes within the network. Among all these heuristic algorithms, a technique that enumerated the candidates to find a global solution for the problems that were Nondeterministic Polynomial-hard was employed.

But, to classify an optimal solution[9] with this algorithm, there was a need for high computational time. For avoiding such numerical challenges and for reducing the burden of computation, there were techniques of metaheuristic optimization as opposed to finding global solutions. Although these metaheuristic algorithms do not always achieve optimum solutions, they can achieve acceptable solutions within a reasonable time frame. This work proposes the hybrid Biogeography-Based Optimization with Tabu Search algorithm for enhancing the mobile ad hoc network routing.

The main contributions of this work are the following:

- Presents a trust-based routing that has a probability of a new packet forwarding to mitigate blackhole attacks.
- Enhances the security for the users accessing to cloud service applications and other mobile ad hoc network users.
- Proposes the hybrid Biogeography-Based Optimization with Tabu Search algorithm for enhancing the mobile ad hoc network routing.

Section 2 presents related works available in the literature. Section 3 details various methods used in this investigation. Section 4 presents' simulation results, and Section 5 presents the conclusion to the work.

2 | RELATED WORKS

Since mobile ad hoc network does not have prior organization and central administration, concerns of security will be different from the other conventional networks. A new mechanism was proposed by Dorai and Rajaram[10] for mitigating the attack of a wormhole in the mobile ad hoc network. There were several techniques of optimization that were able to select an optimal route from the source to the destination. The work further extends both reputation and trust to an improved quality of the link along with channel utilization Ad Hoc On-Demand Multipath Distance Vector. For optimization, Differential Evolution was used.

Sathiyavathi et al[11] propose a novel secure routing protocol for mobile ad hoc networks. The intruder nodes are identified based on the packet delivery model throughout the communication. The Ad Hoc On-Demand Multipath Distance Vector routing protocol is applied, based on the trust model that calculates the trust of nodes and addresses a decision subsequently. A novel dynamic and trust-based routing protocol named Ad Hoc On-Demand Dynamic Trusted Multipath Distance Vector (AODTMDV) had been proposed for implementing efficient and acquired multipath routing in MANETs.

A secure, dynamic, and fast generation of the route was proposed by Upendran and Dhanapal[12] in the Wireless Sensor Networks with route generation metaheuristics. There was a new and modified version of the Particle Swarm Optimization that was employed for the generation of routes. To overcome the local optima issues, the Particle Swarm Optimization was hybridized using Simulated Annealing in the process of selection. Hybridization helped in increasing the speed of the mechanism of route selection, thus reducing overheads of time to a great extent.

Jayabharathi et al[13] had further proposed another Trust-based Bat-Inspired Routing protocol to achieve both contributions. The Trust-based Bat-Inspired Routing protocol proposes trust equations to estimate trust values of every node transmitting data packets. Aggregation process is carried out on the destination node and combines different trust values for obtaining one trust value. In order to get improved transmission, the nodes having higher trust value were selected. Furthermore, the trust level of a node could be gauged by means of fuzzy logic with the aim of making a good routing decision. The next contribution to the Trust-based Bat-Inspired Routing protocol was to estimate all obstacles in the path of communication with the Bat-Inspired Routing-based protocol. This protocol further exploited the method of echolocation to estimate Received Signal Strength Intensity to neighboring nodes from their source nodes. In case the RSSI value for such neighboring nodes is high, the source node can transmit data packets to the destination nodes by means of the chosen neighboring node. A comparison of the performance of the Trust-based Bat-Inspired Routing protocol along with a Lightweight and Dependable Trust System and a Trust Derivation Dilemma Game method showed optimal results in the Trust-based Bat-Inspired Routing protocol.

Roy and Das[14] had made a proposal of a new Group Leader-based Trusted Vehicular Ad Hoc On-Demand Distance Vector where the vehicle will broadcast some important information by means of the Group Leader to that of the other nodes found in the network. For broadcasting any message, the vehicle will have to send a new request to a Group Leader. In case the broadcasted message is not able to come through the Group Leader, other nodes will not consider the information as authentic. In these ways, it will be able to bring down a broadcast storm in the Vehicular Adhoc Network. Recently, Road-Side Unit has been the Group Leader in their area and vehicles are their members. The Road-Side Unit will be taken to be the Group Leader owing to their high processing power without any need to change the Group Leader quickly. Owing to the high mobility of the traits of the Vehicular Adhoc Network, mobility will play a major role in choosing the Group Leader among various vehicles in the area that were based on trust and Slowest Moving Vehicle. The range of transmission of the Road-Side Unit will be more than the range of transmission. Thus, more groups can be formed and all members of the group will be one-hop Group Members. Lastly, it conducts simulation to show the performance of the proposed protocol of Group Leader-based Trusted Vehicular Ad Hoc On-Demand Distance Vector assuming traffic roads are all one-way and vehicles move in one direction.

Mehetre et al,[15] had made a new proposal of another trustable and completely secure scheme of routing with a security mechanism along with a two-stage mechanism of security. Both these schemes will be based on an active trust for protecting many kinds of attacks like the blackhole attack at the time of routing. Thus, the work had identified a trusted path that provides secure paths for routing with the Cuckoo Search algorithm. The parameter of performance in this scheme was energy, and the results of the experiment provided assurance for prolonging the lifespan of the network along with the chances of securing a routing path.

3 | METHODOLOGY

By recognizing the actual importance of such routing policies, the work aims at presenting a policy of multipath routing on the parameters of the trust and metaheuristic algorithms. In this section, a trust model, Biogeography Optimization, and Biogeography-Based Optimization are discussed.

3.1 | Trust model

A trust model will perform functions of derivation, computation, and finally application. Every node will derive the trust factors from the packet forwarding ratio. At the time of computation, a method is used for estimating trust in accordance with trust factors along with a minimal value method that is used for computing the trust of the path. This trust application further includes a route discovery that is trust-based with route selection.

Direct trust[16] was found to be first-hand information for the neighbors, which is very easy to get. If $N_C(t)$ signifies a collective amount of the correct forwarding and $N_A(t)$ denotes the amount of the ones that request within time t, the actual amount of forwarding in the time window (between time t_i-w and t_i) will be $N_C(t_i) - N_C(t_i\text{-}w)$, wherein w is the time window length and $FR\ (t_i)$ is a packet forwarding ratio in its ith window. $FR(t_i)$ is well-defined in 1 as follows:

$$\mathrm{FR(t}_i) = \begin{cases} \dfrac{N_C(t_i) - N_C(t_i - \mathrm{w})}{N_A(t_i) - N_A(t_i - \mathrm{w})} & , \quad t_i > w \\ \dfrac{N_C(t_i)}{N_A(t_i)} & , \quad t_i \le w \end{cases} \tag{1}$$

where $i = 1, 2, 3, \ldots$

The trust for node x to node y was an amount to make sure the packets are transmitted to node y by node x that was sent by node y. These trust values from the Control Packet Forwarding Ratio (CFR) and the Data Packet Forwarding Ratio (DFR) were given weightage for determining trust levels. Direct trust for node y by node x is shown as T_{jk} as in equation 2 as follows:

$$T_{xy}(t_i) = w_1 \times CFR_{xy}(t_i) + w_2 \times DFR_{xy}(t_i), \tag{2}$$

where mutually $CFR_{xy}(t_i)$ and $DFR_{xy}(t_i)$ signifies a Control Packet Forwarding Ratio and Data Packet Forwarding Ratio by the node x to the forwarding node y through time t_i. w_1 and w_2 specify the weights allocated to the Control Packet Forwarding Ratio and the Data Packet Forwarding Ratio, correspondingly.

The following steps are conducted by a trust model for a trusted routing path:

1. Initializing trust-related network statistics with trust values of all network nodes.
2. Updating the statistics of trust-related network and their operations like packet forwarding and packet drop for every node.
3. When the node is established, the destination is asked by broadcast routes.
4. If the route request is established, the destination will send a route reply with the path trust initialized to 0.
5. Intermediate nodes getting route reply will compute trust value with network statistics adding them to the trust path in route reply packets.
6. On receiving a reply by the source node, it is stored in the path, and data packets are sent through them if the source node gets several route replies, they are compared to the trust of the path with trust for the destination storing the path with its maximum trust value.
7. A routing path gets updated at regular intervals to the most-trusted path.

Li et al[16] make use of the trust evaluation and the main disadvantage was the Quality of Service degradation. For overcoming this, Link Quality was considered to be a trust parameter with hops count with 3 as follows:

$$T_{jk}(t_i) = w_1 \times CFR_{jk}(t_i) + w_2 \times DFR_{jk}(t_i) + w_3 \times LQ + w_4 \times HC. \tag{3}$$

3.2 | Biogeography-Based Optimization

The Biogeography-Based Optimization algorithm is based in biogeography that denotes the study of the distribution of plants and animals over space and time. The focus of the field was elucidating the reasons for changing the species distributions in various types of environments. During the early 19th century, biogeography was stated by Charles Darwin and Alfred Wallace after which more researchers had started paying attention to the same.

The Biogeography-Based Optimization and its environment[17] will correspond to an archipelago in which each solution to the problem of optimization will be an island. Every solution feature is known as a Suitability Index Variable. Every solution is known as a Habitat Suitability Index that has a high Habitat Suitability Index for the island that indicates good performance toward the problem of optimisation or a low Habitat Suitability Index that denotes the bad performance of the problem of optimization. Improving the population can solve heuristic problems. The method further generates the subsequent generation of the Biogeography-Based Optimization by establishing the result features to all other islands. It accepts solution features from emigration. The entire population is mutated as in Genetic Algorithms.

The Biogeography-Based Optimization process is as follows:

1. Define the parameter.
2. Initializing population (n islands).
3. Evaluate the rate of immigration and emigration. The good and bad solutions comprise of high and low rates of emigration, respectively, with low and high immigration, respectively.
4. Select immigration islands depending on rates of immigration by roulette wheel selection with emigration rates for selecting emigrating islands.
5. Migrate the Suitability Index Variable chosen arbitrarily on the basis of the chosen islands.
6. Complete mutation based on the mutation probability for all island.
7. Calculating the fitness of every individual island.
8. If the terminating criteria is not reached, go back to step 3; if not, terminate.

3.3 | Proposed Biogeography-Shun Optimization

The proposed Biogeography-Shun optimization is obtained by merging Biogeography Optimization algorithm and Tabu Search. The proposed method is applied to improve the multipath routing. The trust values, energy level, and distance are considered by the algorithm to find optimal routes. The encoding of the problem is detailed here.

3.3.1 | Habitats

Any habitat will be represented by means of a permutation of an integer 1, 2…n, wherein n denotes the actual count of locations which refers to the nodes in the network.

3.3.2 | Initialization

A Biogeography-Based Optimization algorithm begins with randomly generated habitats. Here, the habitat will be represented by means of a permutation of integers. This is generated randomly and is inserted to it for avoiding duplicate habitats and enhancing the chances of its diversity.[18]

3.3.3 | Selection for migration

In the case of a Biogeography-Based Optimization, any good habitat (solution) is the one with the lowest Habitat Suitability Index. All good habitats will share features with the poor ones. The Suitability Index Variable is migrated from the other habitats that are emigrating to the ones that are immigrating. For performing such migration, the immigration rates (λ_k) of the habitat will be employed in order to ensure it is decided if there is a need for modification after which the emigration rates (μ_k) are employed. This is for the other habitats in order to decide if they need to migrate the Suitability Index Variable to its first habitat. Suitability Index Variable in a good habitat (that have low Habitat Suitability Index) will emigrate to a habitat that is poor (that has high Habitat Suitability Index). Thus, any good habitat will have a high μ_k and further a low λ_k, and poor solutions low μ_k with high λ_k.

The rate of immigration λ_k and the rate of emigration μ_k will be computed using equations 4 and 5 given as follows:

$$\lambda_k = I\left(1 - \frac{k}{h}\right), \tag{4}$$

$$\mu_k = \frac{Ek}{h}. \tag{5}$$

In these equations, k indicates the rank of any habitat once they are sorted in accordance with their respective Habitat Suitability Index. The habitats that have a high level of Habitat Suitability Index (or a poor solution) will have a rank that is lower, and the habitats that have a low Habitat Suitability Index will have a rank that is higher. The habitats become arranged from the worst one to the best. The h signifies actual count of habitats found in the population, and I states the rate of maximum immigration, while E is the rate of maximum emigration that is set to 1.

3.3.4 | Mutation

In the case of Biogeography-Based Optimization, every habitat will have a connected probability in order to become a solution to a certain problem. This probability as to whether mutation takes place within the habitat is known as the rate of mutation. For determining the rate of mutation for every such habitat, it evaluates the probability of species count through formula 6 as follows:

$$p = \frac{v}{\sum_{i=1}^{h+1} v_i}. \tag{6}$$

Here, V and V$_i$ are assessed by 7 as follows:

$$\begin{aligned} v &= [v_1, v_2 \dots v_{h+1}]^T \\ v_i &= \begin{cases} \dfrac{h!}{(h+1-i)!(i-1)!} & \left(i = 1, 2, \dots, i'\right) \\ v_{h+2-i} & \left(i = i'+1, i'+2, \dots, h+1\right) \end{cases}, \end{aligned} \tag{7}$$

wherein $i' = \text{ceil}((n + 1)/2)$. Mutation rate ($m$) is inversely proportional to the species count probability as in 8 as follows:

$$m(S) = m_{\max}\left(\frac{1-P_s}{P_{\max}}\right), \tag{8}$$

wherein $m_{\max}$ is the maximum mutation rate and $P_{\max}$ is the largest species count probability.

3.3.5 | Migration operator

As referred to before, all Suitability Index Variables from any good habitat will migrate into a habitat that is power. This type of migration operator will be probabilistic based on rates of immigration or emigration. Here, it is explained as to how such migration can be incorporated into the proposed Biogeography-Shun Optimization algorithm.

As soon as a fresh habitat gets produced, it can be accepted by the population solely in case of it not being similar to an existing one. This helps in enhancing the level of diversity among the population. It also uses a concept of elitism for preventing solutions from getting corrupted by means of immigration, through setting the rate of immigration for the best solutions to 0.

3.3.6 | Mutation operator

As per biogeography, there are cataclysmic events that take place, and these can change the traits of a natural habitat to a significant level. In a Biogeography-Based Optimization algorithm, this will be imitated by means of a mutation operator. The progression is crucial to increasing population diversity.

The mutation will be achieved by replacing the chosen Suitability Index Variable for a certain habitat using a Suitability Index Variable that is generated randomly. It has to be remembered that in Biogeography-Based Optimization, a migration operator will be part of a strategy of intensification and a mutation operator will be used for maintenance of diversity. The habitats of a population will then be upgraded by this migration operator in the whole iteration of a Biogeography-Based Optimization algorithm. But, the effort can get affected adversely by a mutation operator owing to the quality of such mutated habitats not be guaranteed. In most cases, the process of mutation will bring about a poor habitat.

One easy solution for such drawbacks is that once a mutation is performed, all mutated habitats will be kept inside the population if the quality is found to be better compared to the original habitats. But, it may not be practical while solving a complex problem in optimization. In most cases, the habitats that result from simple mutation operators may not be better compared to original habitats when there is a convergence of the algorithm.

In order to overcome such a weakness of the Biogeography-Based Optimization algorithm, there was a proposal to get the mutation operator replaced using a TS process. The Tabu Search that was proposed by Glover was a meta-heuristic that performed a local search that was based on information found in memory. The Tabu Search was iterative and neighborhood-based as well. For every iteration, the current solution makes a move to its neighborhood solution using the best value. For the purpose of avoidance of trapping within the local optima, there was a move made to store this within the TABU list and also a reserve move to the earlier solutions which was forbidden. The final presentation of the TABU search was dependent on the kind of neighborhood and the employment of the TABU list.

The primary advantages found in replacing mutation operators for the traditional Biogeography-Based Optimization that uses the Tabu Search will come in two different points. First, the mutation is maintained and this was to bring about an increase in the population and its diversity. Aside from this, it is ensured that the quality of the resultant habitats does not get ruined. For the purpose of proving this statement, there were two Biogeography-Based Optimization algorithms developed, as follows:

i. The traditional Biogeography-Based Optimization along with a mutation operator and
ii. Biogeography-Based Optimization hybridized with Tabu Search.

There was a Suitability Index Variable of the habitat that was chosen for mutation that was based on the rate of mutation. This procedure was achieved by means of replacing the older Suitability Index Variable with other Suitability

Index Variable that were generated randomly to inherit all original values of mutated Suitability Index Variable. So, the resultant habitat is feasible.

In this work, it is proposed to replace the mutation operator of Biogeography-Shun Optimization with a robust TABU search. TABU list for the Robust TABU Search contains pairs of various facilities that will not be exchanged, and all of the latest iteration wherein the pair of such facilities that are placed will also be stored. There can be a swap of such facilities, but this is considered a taboo for the iterations in case they were swapped in their final iteration. But such a move is permitted in case an improved objective function is obtained compared to the current best solution. The tenure of TABU for the Robust TABU Search will change from 0.9 to 1.1 n in a dynamic manner.

The primary advantage of the Robust TABU Search is that it is more robust and efficient. Its robustness makes it less complex with only a few parameters for implementation. For Biogeography-Shun Optimization, the rate of mutation will become the probability that any habitat within the population can go through the process of Robust TABU Search. The actual number of such iterations in the Robust TABU Search and the number of other iterations within this work will make use of lower iterations. This is owing to the fact that the Robust TABU Search found in the Biogeography-Shun Optimization will be limited to quick searches. The habitat that results from this Robust TABU Search procedure replaces its original habitat in case the population does not have a similar habitat until now.

4 | RESULTS AND DISCUSSION

The performance of the proposed Biogeography-Shun Optimization was evaluated for 5% and 10% malicious network and compared with Trust based Ad Hoc On-Demand Multipath Distance Vector Routing. Table 1 shows the Parameters

TABLE 1 Simulation parameters

Parameters	Values
Number of nodes	300
Network size	1,000 m * 1000 m
Initial energy level	15 J
Transmission range	250 m
Routing protocol	AOMDV
Node pause time	10, 30, 50, 70, 90
Habitat modification probability	1
Immigration probability bounds per gene	[0. 1]
Maximum immigration and migration rates for each island	1
Mutation probability	0

TABLE 2 Packet delivery ratio for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

	For 5% malicious		For 10% malicious	
Node pause time (seconds)	Trust	Biogeography-Shun Optimization-AOMDV	Trust	Biogeography-Shun Optimization-AOMDV
10	0.739	0.7995	0.7221	0.7947
30	0.8325	0.906	0.7895	0.8571
50	0.8598	0.9398	0.8401	0.9138
70	0.862	0.9489	0.8421	0.9204
90	0.8871	0.9721	0.8101	0.89

TABLE 3 Average end-to-end delay for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

Node pause time (seconds)	For 5% malicious		For 10% malicious	
	Trust	Biogeography-Shun Optimization-AOMDV	Trust	Biogeography-Shun Optimization-AOMDV
10	0.0086	0.0071	0.0144	0.0125
30	0.0014	0.0012	0.0047	0.004
50	0.0014	0.0013	0.0031	0.0026
70	0.0012	0.001	0.0014	0.0012
90	0.001	0.0009	0.0012	0.0011

TABLE 4 Average number of hops to destination for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

Node pause time (seconds)	For 5% malicious		For 10% malicious	
	Trust	Biogeography-Shun Optimization-AOMDV	Trust	Biogeography-Shun Optimization-AOMDV
10	5.2	5.8	5.8	6.3
30	5.2	5.6	5.2	5.7
50	4.4	4.8	4.8	5.2
70	4.7	5.1	4.7	5.1
90	3.4	3.7	3	3.3

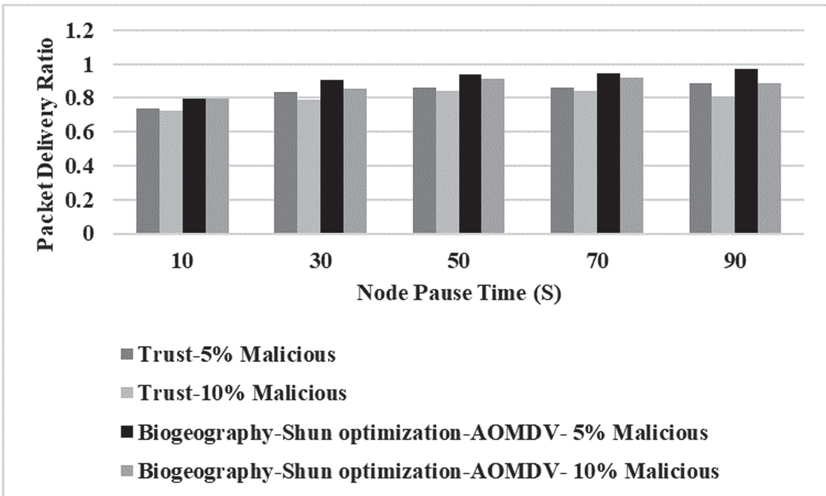

FIGURE 1 Packet delivery ratio for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

of Mobile Adhoc Network. The Packet Delivery Ratio, average end to end delay, average number of hops to the destination, as well as the percentage of malicious nodes detected are denoted in Tables 2 to 4 and Figures 1 to 4.

Figure 1 and Table 2 show that the Biogeography-Shun Optimization-AOMDV 5% malicious has higher Packet Delivery Ratio by 7.86%, 10.17%, and 0.6% for 10 node pause time, by 8.45%, 13.74%, and 5.54% for 30 node pause time, by 8.89%, 11.2%, and 2.8% for 50 node pause time, by 9.59%, 11.92%, and 3.04% for 70 node pause time, and by 9.14%, 18.17%, and 8.82% for 90 node pause time than with trust 5% malicious, trust 10% malicious, and Biogeography-Shun Optimization-AOMDV 10% malicious, respectively.

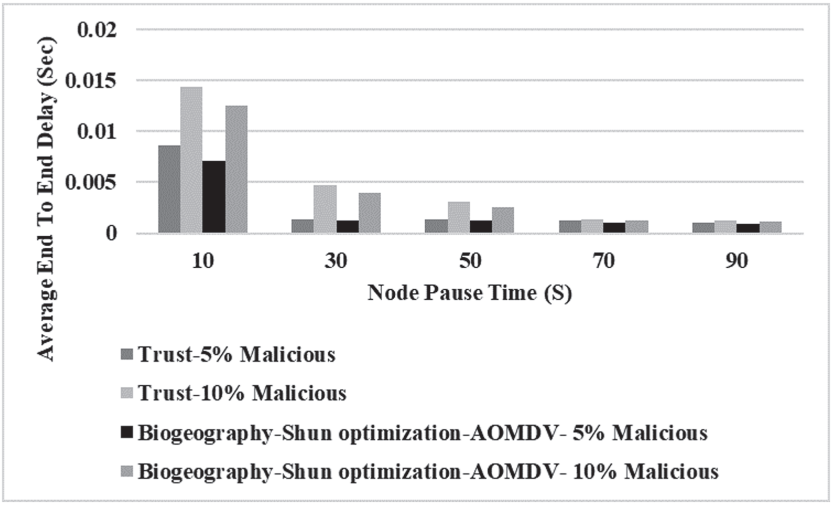

FIGURE 2 Average end-to-end delay for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

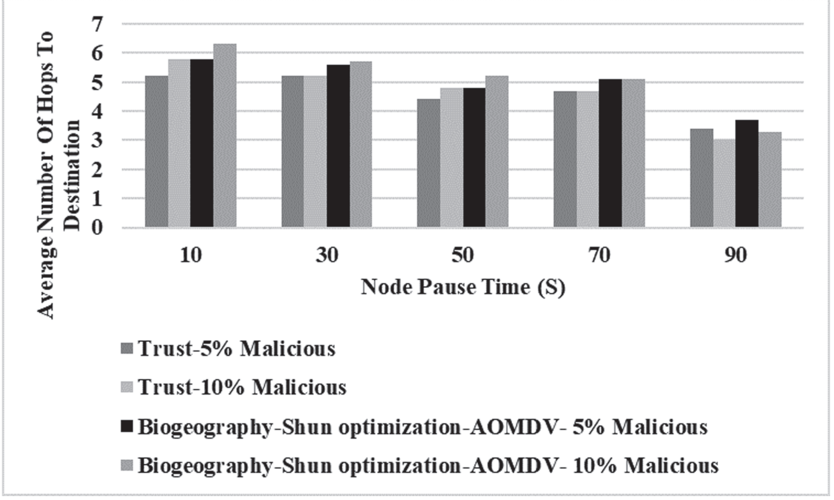

FIGURE 3 Average number of hops to destination for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

Figure 2 and Table 3 show that the Biogeography-Shun Optimization-AOMDV 5% malicious has lower average end to end delay by 19.1%, 67.9%, and 55.1% for 10 node pause time, by 15.38%, 118.64%, and 107.69% for 30 node pause time, by 7.41%, 81.81%, and 66.67% for 50 node pause time, by 18.18%, 33.33%, and 18.18% for 70 node pause time, and by 10.52%, 28.57%, and 20% for 90 node pause time than trust 5% malicious, trust 10% malicious, and Biogeography-Shun Optimization-AOMDV 10% malicious, respectively.

Figure 3 and Table 4 show that the Biogeography-Shun Optimization-AOMDV 5% malicious has a greater average number of hops to destination by 10.91% and same value for 10 node pause time, by 7.41% and 7.41% for 30 node pause time, by 8.69% and same value for 50 node pause time, by 8.16% and 8.16% for 70 node pause time, and by 8.45% and 20.89% for 90 node pause time than trust 5% malicious and trust 10% malicious. The Biogeography-Shun Optimization-AOMDV 5% malicious has a lesser average number of hops to destination by 8.26%, 1.76%, 8%, same value, and 11.42% for Biogeography-Shun Optimization-AOMDV 10% malicious than 10, 30, 50, 70, and 90 node pause times, respectively.

Figure 4 and Table 5 show that the Biogeography-Shun Optimization-AOMDV 10% malicious has higher percentage of malicious nodes detected by 6.89% compared for trust 5% malicious, by 4.54% compared for trust 10% malicious, and by 2.24% than for Biogeography-Shun Optimization-AOMDV 10% malicious, respectively.

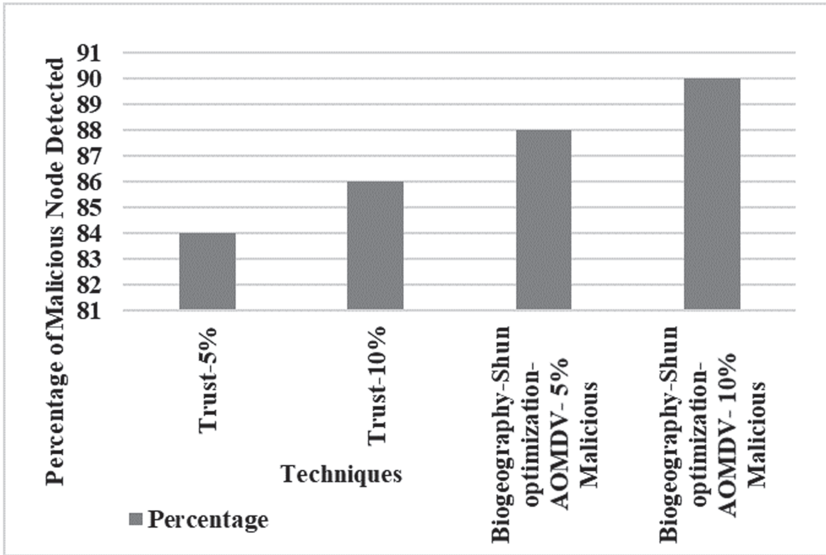

FIGURE 4 Percentage of malicious nodes detected for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

TABLE 5 Percentage of malicious nodes detected for Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing

	For 5% malicious		For 10% malicious	
	Trust	Biogeography-Shun Optimization-AOMDV	Trust	Biogeography-Shun Optimization-AOMDV
Percentage (%)	84	86	88	90

5 | CONCLUSION

Cloud computing delivers computing resources, services over the network using Internet. The mobile ad hoc network refers to a network that is infrastructureless. It can be a challenging task to design a scheme of multipath routing owing to the fact that it can be very dynamic within the mobile ad hoc network environment. In order to provide a reliable and optimal routing, this work adapted the Biogeography-Based Optimization technique which is based on the concept of Biogeography for optimizing the routing. The Tabu Search refers to a heuristic procedure that is employed to solve problems in optimization.

The Classical Biogeography-Based Optimization algorithm works a mutation operator in place of its approach for diversification. The step tends to destroy the habitats and their quality in the population. In the Biogeography-Shun Optimization algorithm proposed, the Robust TABU Search had replaced the mutation operator. The population and its diversity is duly maintained, and it is ensured that the habitats and their quality do not get ruined. Results show that the Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing 5% malicious has greater Packet Delivery Ratio by 7.86%, 10.17%, and 0.6% for 10 node pause time, by 8.45%, 13.74%, and 5.54% for 30 node pause time, by 8.89%, 11.2%, and 2.8% for 50 node pause time, by 9.59%, 11.92%, and 3.04% for 70 node pause time, and by 9.14%, 18.17%, and 8.82% for 90 node pause time than trust 5% malicious, trust 10% malicious, and Biogeography-Shun Optimization-Ad Hoc On-Demand Multipath Distance Vector Routing 10% malicious, respectively. In future work, the accuracy can be improved with malicious state of node.

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REFERENCES

1. Yaqoob I, Ahmed E, Gani A, Mokhtar S, Imran M, Guizani S. Mobile ad hoc cloud: a survey. *Wireless Communications and Mobile Computing*. 2016;16(16):2572-2589.

2. Alam T, Benaida M. The role of cloud-MANET framework in the internet of things (IoT). 2019; arXiv preprint arXiv:1902.09436.
3. Malik M, Yadav P, Dureja A. Performance analysis of load balancing in MANET using on-demand multipath routing protocol. *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)*. 2014;3(6):2106-2110.
4. Prasad DMS, Niranjan P, Swathi B. An effective method for load balancing in MANET. *Int J Comput Sci Mob Comput*. 2014;3(6): 223-229.
5. Alam T. Middleware implementation in cloud-MANET mobility model for internet of smart devices. 2019; arXiv preprint arXiv: 1902.09744.
6. Royer EM, Perkins CE. An implementation study of the AODV routing protocol. In *2000 IEEE Wireless Communications and Networking Conference. Conference Record (Cat. No. 00TH8540)* 2000; September (Vol. 3, pp. 1003-1008). IEEE.
7. Thorat SA, Kulkarni PJ. Design issues in trust based routing for MANET. In *Fifth International Conference on Computing, Communications and Networking Technologies (ICCCNT)* 2014; July (pp. 1-7). IEEE.
8. Garg D, Gohil P. Ant colony optimized routing for mobile ad hoc networks (MANET). *International Journal of Smart Sensors and Ad Hoc Networks (IJSSAN)*. 2012;2(3):8-13.
9. Gulzar CM, Paul KS, Tahseen B. Optimal path in wireless ad hoc network (WANET) and mobile ad hoc network (MANET). *TEST Engineering & Management*. 2020;82:1794-1798.
10. Dorai R, Rajaram M. Trust and reputation mechanism with path optimization in multipath routing. *International Journal of Electrical, Computer, Energitic, Electronic and Communication Engineering*. 2015;9(3):385-391.
11. Sathiyavathi V, Reshma R, Parvin SS, SaiRamesh L, Ayyasamy A. Dynamic trust based secure multipath routing for mobile ad-hoc networks. In: *Intelligent Communication Technologies and Virtual Mobile Networks*. Cham: Springer; 2019, February:618-625.
12. Upendran V, Dhanapal R. Dynamic secure multipath routing in wireless sensor networks using modified simulated annealing based particle swarm optimization. *International Journal of Computer Applications*. 2016;154(5):18-23.
13. Jayabharathi K, Ranganathan V, Kishore R. An efficient trust based bat-inspired routing (TBIR) protocol for MANET. *Int J Adv Engg Tech* /Vol VII/Issue II/April-June. 2016;7(2):721–730.
14. Roy D, Das P. Trust and group leader based model to avoid broadcast storm problem in vehicular ad-hoc networks. *Advances in Computational Sciences and Technology*. 2017;10(4):575-597.
15. Mehetre DC, Roslin SE, Wagh SJ. Detection and prevention of black hole and selective forwarding attack in clustered WSN with active trust. *Cluster Computing*. 2019;22(1):1313-1328.
16. Li X, Jia Z, Zhang P, Zhang R, Wang H. Trust-based on-demand multipath routing in mobile ad hoc networks. *IET Information Security*. 2010;4(4):212-232.
17. Zhao F, Qin S, Zhang Y, Ma W, Zhang C, Song H. A two-stage differential biogeography-based optimization algorithm and its performance analysis. *Expert Systems with Applications*. 2019;115:329-345.
18. Zhao F, Du S, Zhang Y, Ma W, Song H. Hybrid biogeography-based optimization with enhanced mutation and CMA-ES for global optimization problem. *Service Oriented Computing and Applications*. 2020;14(1):65-73.

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