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ANALYSIS OF SWARM INTELLIGENCE ROUTING PROTOCOLS IN LARGE-SCALE MOBILE AD HOC NETWORKS (MANET'S)

[1]MUHAMMAD AHSAN, [2]SAMMER ZAI, [3]DILEEP KUMAR, [4]ASAD ABBAS*, [5]FAWAD ALI
[1,2,5]Mehran University of Engineering and Technology, Jamshoro, Department of Computer System Engineering, Pakistan
[3]Quaid-e-Awam University of Engineering Science and Technology, Nawabshah, Department of Computer Systems Engineering, Pakistan
[4]University of Central Punjab, Lahore, Faculty of Information Technology, Pakistan

*Corresponding Author

E-mail: [1]ahsan.ansari@faculty.muet.edu.pk, [2]sammer.zai@faculty.muet.edu.pk, [3]dileep.kumar@quest.edu.pk, [4*]asadabbas.grw@ucp.edu.pk, [5]fawad.mangi@faculty.muet.edu.pk

ABSTRACT

Mobile Ad-hoc Network (MANET) is a network of mobile devices which are connected wirelessly. This network is a self-configuring network as it rebuilds its topology and information in the routing table for exchanging the data packets every time whenever a node either joins or leave the ad-hoc network. Due to the distinct characteristics of this network including dynamic topology, hop-by-hop communication and speedy set-up, MANETs face various issues primarily including routing, security, and clustering. As the use of wireless devices and the wireless networks is going to be increased day by day, so it is required to improve the working of such networks. It is assumed that the framework of mobile networks may be improved by taking inspirations from the biological structures of high-spirited. This study aims to compare Swarm Intelligence based routing protocols specifically Ant-Net and Honeybee-based routing algorithms in MANET that may help the researchers in selection of a routing protocol when working with MANETs. These algorithms work adaptively towards the intelligence behavior of ants and bees which these insects use for searching food from their colonies or hives. Extensive experiments have been performed using Network Simulator 2 (NS2) for a comprehensive analysis and examination of the selected protocols by considering performance metrics including end-to-end delay and throughput.

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Keywords: *MANET, AntNet, BeeIP, Swarm Intelligence, wireless network.*

1. INTRODUCTION

The innovations in the field of internet is because wireless network-based technologies are giving a rise to various new applications. Amongst all fields, MANET is the most noticeable area for research as well as development of wireless network [1]. MANET describes a network of mobile nodes (smart phones, Personal Delivery Assistant (PDA), laptops etc.) with a wireless connection in between them and without having an access point as depicted by Fig 1 In MANET, communication takes place between nodes via radio signals without having a central administrator [2]. In MANET, communication link breakage is quite frequent since nodes can move freely in a network.

Figure 1: Mobile Ad-hoc Network

A group of autonomous self-organized nodes is called as Mobile Adhoc Network, MANET [3-4]. The communication in MANET's takes place through a wireless medium. Consequently, the two

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nodes organized in a multi-hop manner may communicate with each other in this network only if these nodes come within their range of transmission medium as shown in Fig.1 which represents a basic scenario of MANET's where participating nodes comprise of mobiles.

MANET's have embraced/utilized/used various conventional algorithms for routing, however swarm intelligence (SI) based routing algorithms have captured the attention of various researchers in last couple of years. These algorithms search for the optimized solution based on heuristic information [5]. SI is a collective behavior of self-managed and decentralized system. Collective behavior refers to the processes which emerge in a spontaneous way. Since, a MANET does not make use of any extant framework therefore, also familiar as infrastructure-less network [6]. Routing in a network is described by the construction and maintenance of a working path(s) between the participating devices called nodes that wants to have communication by switching data packets with each other [7].

Routing is one of the key factors that may affect the performance of the network hence it is necessary to take care of the route. The primary objective of routing algorithms is to define a path from source to destination that maximizes the performance of the network while keeping the minimum cost. Moreover, routing focuses on diagnosing, enrolling, and disseminating the paths from source node to the destination node. However, it appears a quite challenging task in MANET's since in this network the participating nodes move in an arbitrary fashion without constant speed hence results in connectivity issue that may split the connection among the hosts. The routing protocols in MANET's are categorized in three classes: proactive, reactive and hybrid [4,8]. Proactive protocols are also familiar as global protocol. In this routing protocol, each of the participating nodes keeps the knowledge of every other node in a table therefore, also known as table-driven routing protocol [9-10]. The second category of routing protocol is the reactive protocol which is also known as on-demand routing protocol because it finds out the route by utilizing a route discovery process whenever asked by the source node. Whereas, hybrid protocols [11] such as Zone Routing Protocol (ZRP) groups the fundamental characteristics of both first and second categories of routing protocol therefore, this category is both reactive and proactive in nature. It works by maintaining the routes to nearby nodes in a proactive manner while the routes to the far away nodes are determined by adopting a route discovery technique.

2. RELATED WORK

MANETS have given rise to various applications including wireless sensor networks [12-13], data networks, device networks, etc. The primary objective of MANET is to lengthen into the territory of mobiles that may combine routers and hosts in a way that they establish the network routing infrastructure in an ad-hoc manner. Various security threats are faced in a wireless network. Although, many solutions have been proposed in the literature to overcome these threats but still this area needs to be researched. Robust and efficient routing functionalities in between mobile nodes is the primary vision of MANETs.

Besides, scalability is also considered as one of the primary issues when one is going to implement such ad-hoc networks. Many of the existing network management algorithms either support static or comparatively small wireless networks. However, there are various applications of MANET that comprises of large number of nodes such as sensor networks and tactical networks. Implementation of such networks involve various issue that are still a great topic of research [14]. These challenging issues may include routing, location management, security [15], maintaining network topology [16] addressing and many more. Since the communication is wireless and each node within the ad-hoc network is receiving the packet within its wireless vicinity regardless of packet's destination, therefore it is quite challenging to keep MANET secure from mischievous attacks [17]

In [7], authors have proposed one of the routing protocols based on the swarm intelligence. In their study, they have presented multi-path routing algorithm after getting an inspiration from the characteristics of a bee. The authors in [18] have presented a survey regarding the security challenges and issues in MANET. In their study, different defeating approaches have also been presented. Another research has been presented in [19] where a novel routing scheme has been presented based on the AntNet protocol and ring search and local retransmission technique (RSLR). According to this study, their algorithm decreases the routing message overheated as well as end-to-end delay. However, [20] presented a review study of SI based algorithms for MANET's.

In this paper, the performance of swarm intelligence based routing protocols specifically

AntNet and BeeIP are compared and analyzed comprehensively by determining their performance using QoS parameters such as end-to-end delay, overhead, and throughput in different topological arrangements such as ring and star topologies with varying number of nodes by using Network Simulator 2 (NS2).

3. MATERIALS AND METHODS

Swarm Intelligence provides solution of complex problems through communication and intelligent behavior of thousands of self-governing decentralized swarm members [21]. Based upon different behaviors of Ants and Honeybees a number of algorithms have been proposed globally. But, a number of issues need to be addressed prior to choosing a specific version of a routing protocol for an application environment. Several algorithms that may work well in a small network structure may not be able to perform well if the size of the network is increased. Hence, it is important to know under what circumstances, network configuration and application environment, a swarm intelligence-based routing protocol's performance may be optimized.

The concept of Swarm intelligence is an inspiration from the intelligence used by the species such as Ants, bees, fishes, wasps, etc for performing their different activities. The techniques based on the swarm intelligence comprises of Ant Colony Optimization (ACO), Bee Colony Optimization (BCO), and Particle Swarm Intelligence (PSO).

Analysis and evaluation of two swarm intelligence-based protocols, ant-based and honeybee-based specifically is presented. Investigation has been carried out in order to know the performance of the two protocols for large-scale MANET structure while changing application environment and network configuration.

3.1 Ant Colony Optimization (ACO)

Ant Colony Optimization (ACO) is a technique that is inspired from behavior and activities of ants such as the activity performed in order to search the food and strategies carried out to build their nests. It is found that naturally ants have the power to find out the shortest path towards their food from their nest. ACO algorithm has been a good selection towards finding an optimal traversal path [22]. However, searching for the shortest path is a difficult task but the ants perform this task by cooperating with each other in their colony systems which makes their complex task easy through the help of individuals in the colony. This is the major inspiration that has caught the attention of various researchers to implement the same concept for exchanging the data packets in between participating nodes in MANET's. Besides, while walking towards the food and back to the nest, ants drops a chemical substance known as pheromone which leaves a mark on the route for the later identification. The other ants in the colony can smell this chemical substance and also are able to differentiate its concentration which helps them in selection of their route. The property of the pheromone is that its concentration decreases with time therefore, with this property it can be identified that the route is less occupied due to deterioration. Figure 2 exhibits the behavior of ants for the selection of the best route.

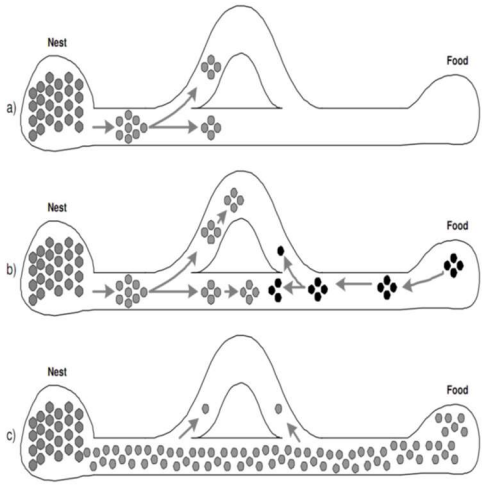


Figure 2. All ants take the shortest path after an initial searching time. [23]

The overall similarities between ants and the MANET's can be clearly understood by looking at the Table 1. This table provides a clear picture of why ants behavior is used as an inspiration for the routing algorithms. There are various ACO based routing algorithms used for MANET's, but this study focuses on AntNet routing algorithm.

Table 1: Behavior of Ants and Ad-hoc Network

Parameters	Behavior of Ad-hoc Network	Ant's Behavior
Physical Layout	Non-Structural, Dynamic, Distributed	Non-Structural, Dynamic, Distributed
Route's origin	Source node sends the route request to get the local information.	Uses pheromones for constructing new routes
Support for multi-path	Single path, Multipath in partial	offers multipath
Fundamental System	Self-managing, Self-organizing	

3.1.1 AntNet

AntNet is an algorithm for adaptive best-effort routing in IP networks. AntNet's design is based on AntNet routing protocol has been designed in a way that it performs quite closer to that of original ant's behavior. Usually, this routing algorithm works in terms of two groups of artificial ants; one is called forward ant or forward agent and the other is called backward ant or backward agent. Although, the ants in both groups comprise of the similar structure but they are located at different environments means both groups can sense different inputs and accordingly produce different independent outputs [24]. These groups are created for the reason so that the ants coming backward can use the information gathered by the group of forward agents.

Considering node 's' from network, the forward group is presented from source to destination 'd' in order to find out the best reasonable path with low cost and to inspect the status of overall load along the path at regular intervals t. The forward agents keep and store he data for every node they visit along with an opportunity to have an ideal path from source as shown in Fig 3. After the forward group reaches to the destination, most of its data is saved as a stack of backward agents which begin to travel the destination by popping out the data at each node being traversed from the stack. Moreover, the nodes are updated accordingly.

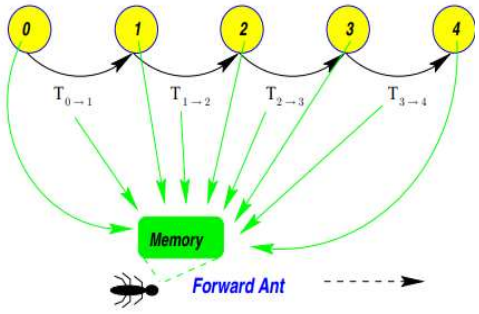


Figure 3. Forward ants keep memory of each visited node and of the visiting time

When the destination node d is reached, the forward agent Fs→d is virtually transformed into another agent Bd→s called backward ant, which inherits all its memory as shown in Fig.4.

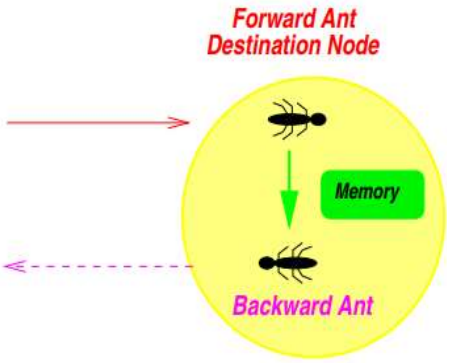


Figure 4: Transformation of the Forward Ant into Backward Ant

The backward ant takes the same path as the one followed by the corresponding forward ant, but in the opposite direction [25]. At each node 'k' along the path the backward ant knows to which node it has to move to next by consulting the ordered list Vs→k of the nodes visited by the forward ant. As shown in Fig.5. Backward ants do not share the same link queues as data packets. They use higher priority queues, because their task is to quickly propagate to the nodes the information accumulated by the forward ants during their journey from s to d.

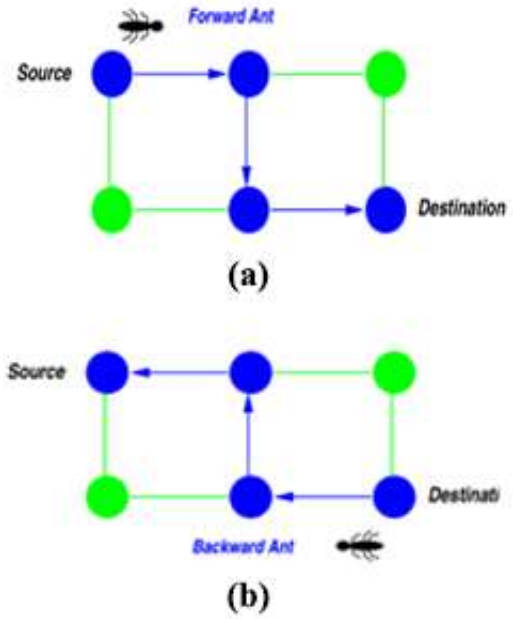


Figure 5: Forward and backward ants visit

3.2 Bee Colony Optimization

Like ACO, the Bee Colony Optimization (BCO) [26-27] is a meta-heuristic propelled by nature, which can be connected to discover answers for the troublesome issues of optimization. In this category of swarm intelligence-based routing algorithms, during the first pass known as forward pass, artificial bees search for a partial solution of the problem after it is defined. Once the enough information is gathered by these bees, they return to the hives where they share the obtained partial solution to the problem among the searchers. In this regard, based on some probability each of the bees must decide of whether to follow its own decided routing path or to switch to the fellow searcher's routing path. Based on certain criteria, the best solution is decided.

3.2.1 BeeIP Routing Protocol

An adaptive routing protocol inspired by the characteristics of honeybee that is collaborative behaviors of honeybee foragers. Whenever the data is needed to be transmitted between nodes then the honeybee agents of BeeIP explore the topology. The agents are directed to monitor and evaluate the performance of the discovered paths and select the best optimal solution based on mechanism inspired by their natural counterparts [28-30]. Based on the inspiration from the swarm intelligence, several assumptions regarding agents are made by this routing protocol that may include agents in use, their behavior and communication between them. Assumptions are generally made in order to map the corresponding concepts of their natural counterparts. In BeeIP, besides the obvious mapping, honeybee hive is considered as a source node, the source of food(flower) is considered as the destination, whereas the flying distance to be traversed from the hive to flower represents the intermediate nodes.

A good thing about the BeeIP protocol is that it constantly monitors, evaluates, and assess the quality of the obtained paths by comparing the new quality measures with the previous ones. Natural foragers consider various quality factors which may represent the improvement over time. The characteristic of adaptivity offered by the improvement over time can be mapped from nature to networks, this characteristic is one of the basic ideas behind any adaptive routing protocol in swarm intelligence-based working. Responding to the changes by adjusting the routing path may enhance the self-healing property of the protocol and helps its scalability to different size of the network and varying conditions. The agents of BeeIP can work in parallel adaptively. These agents may communicate to exchange the simple information that has been gathered from different networks with each other and attains multi-path routing at the global level.

Swarm intelligence components of BeeIP allows this protocol to tackle the failures in the network for instance losing an agent that is packet loss or the loss of an intermediate node of a path from source to destination may cause a disruption to the proposed routing solution. In case of a failure situation, the BeeIP protocol invokes the alternate solutions. Also, distribution of the workload causes the computational cost to be distributed amongst the nodes that involve in any of the network activities. Hence, the important mechanisms of this protocol may involve adaptive scouting, foraging, selection of optimal path, and detection of path failure [31].

4. EXPERIMENTAL RESULTS

In order to analyze and compare the performance of two swarm intelligence-based routing protocol, AntNet and BeeIP, an extensive experimental work has been carried out. To design and implement the network, an event-driven simulation tool known as NS 2 Network Simulator 2 has been used. This simulator provides an ease to set the parameters that may include routing algorithm, traffic details, topology, etc and supports Tool Command

Language (TCL), Simulation scripting language, C, C++ language.

For evaluation and analysis of the routing protocols, this study uses three performance measures including end-to-end delay, throughout, and communication overhead. The analysis is carried out by designing a network model with varying number of network nodes that is 20, 50, and 100. For each of the network model, varying number of mobile nodes are arranged in two different topologies and results are observed. Specifically, this study focuses on ring and star topology of the mobile nodes in a network model. Various simulation parameters have been set as shown in Table 2 in order to test the two routing protocols; AntNet and BeeIP.

Table 2: Simulation Parameters

Simulation Parameters	Values
Channel Type	Channel/ Wireless Channel
Radio Propagation Model	Propagation/ Two Ray Ground
Network Interface Type	Phy/Wireless Phy
Mac Type	Mac 802.11
Antenna Model	Anteena/ Omni-Antenna
Maximum Packet in ifq	50
Number of Mobile Nodes	20, 50, 100
Packet Size	200 bytes
Energy in Joules	10000
Routing Protocols	AntNet, BeeIP
Traffic Type	UDP
Topology	Ring, Star
Simulation Area	600 * 600

4.1 Evaluation Parameters

For the purpose of analysis, two performance measures are adopted that include end-to-end delay ad throughput which are defined below.

4.1.1 End-to-End Delay

End-to-End Delay represents the time taken by a packet for its transmission from source to destination.

$$End - to - end\ delay = \sum e/p \quad (1)$$

Where

$$e = T_d - T_s$$

Td= Receiving time of the packet received at destination

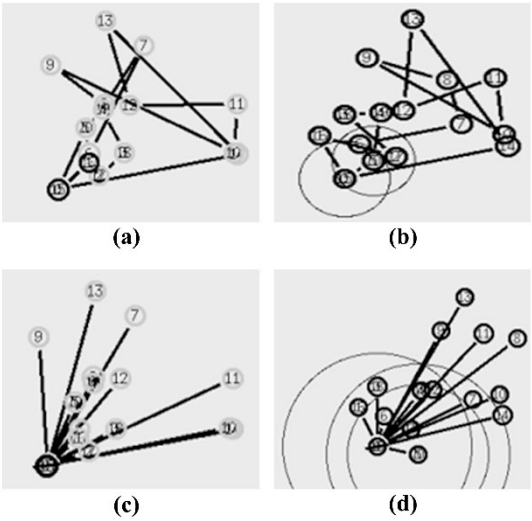
Ts= Sending time of the packet

p= Total packets received by the node

4.1.2 Throughput

Throughput defines the overall information obtained by the destination. It describes the successful movement of data from source to destination in a specified time period.

Figure 6 represents the simulation using AntNet protocol for delay computation between twenty nodes in ring and star topology respectively.



Figue 6: AntNet Simulation for delay computation using ring and star topology with 20 nodes

Figure 6(a) shows the network model with ring topology having 20 nodes drawn in network animator which initiates the network communication. The communication is initiated by node number 6, 12, 13, and 15. Out of twenty nodes, five nodes are static whereas fifteen nodes are in mobility. However, Fig. 6(b) shows the transmission of packet between given nodes. Whereas, Fig. 6(c) represents the network initialization phase for the scenario of star topology with nine static nodes and

eleven mobile nodes where communication within network is initialized by nodes one to nine and fourteen to twenty. However, Fig. 6(d) represents the delay computation between given nodes for star topology.

Figure 7 represents the simulation using BeeIP protocol for delay computation between twenty nodes in ring and star topology respectively. Figure 7(a) shows the network model with ring topology specifically having 20 nodes drawn in network animator which initiates the network communication. The communication is initiated by nodes one to eight and fifteen to twenty. All the nodes in this scenario are mobile nodes. However, Fig. 7(b) shows the transmission of packet between given nodes using BeeIP protocol. Whereas, Fig. 7(c) represents the network initialization phase for the scenario of star topology with nineteen mobile nodes where communication within network is initialized by nodes one to seven and fourteen to twenty. However, Fig. 7(d) represents the delay computation between given nodes for star topology.

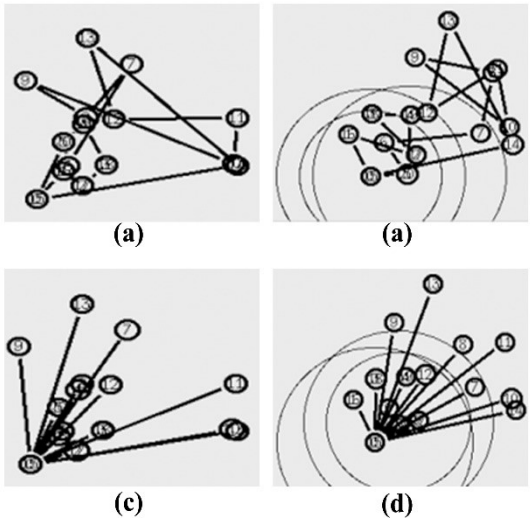


Figure 7: BeeIP Simulation for delay computation using ring and star topology with 20 nodes

Similar models are simulated using AntNet and BeeIP protocol for throughput computation between twenty nodes arranged in ring and star topology respectively.

Figure 8 represents the simulation using AntNet protocol for throughput computation between twenty nodes network simulator arranged in ring and star topology respectively. Figure 8(a) shows the network model with ring topology specifically having 20 nodes drawn in network animator which initiates the network communication. The communication is initiated by nodes one to eight and fifteen to twenty. All of the nodes in this scenario are mobile nodes. However, Fig. 8(b) shows the transmission of packet between given nodes using BeeIP protocol. Whereas, Fig. 8(c) represents the network initialization phase for the scenario of star topology with nineteen mobile nodes where communication within network is initialized by nodes one to seven and fourteen to twenty. However, Fig. 8(d) represents the delay computation between given nodes for star topology.

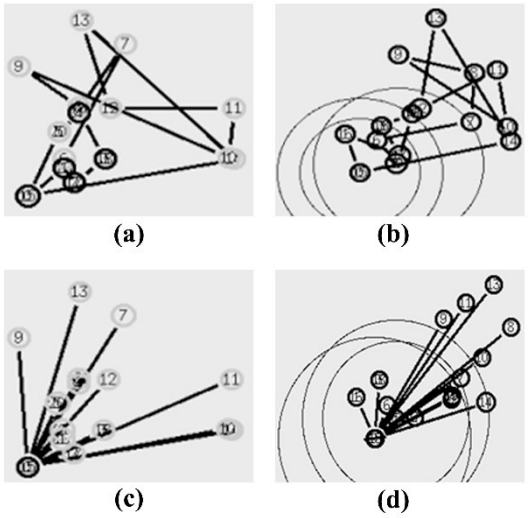


Figure 8: AntNet Simulation for throughput computation using ring and star topology with 20 nodes

Figure 9(a) shows the network model with ring topology specifically having 20 nodes drawn in network animator which initiates the network communication. The communication is initiated by nodes one to eight and fifteen to twenty. Out of twenty nodes, two nodes are static whereas eighteen nodes are in mobility. However, Fig. 9(b) shows the transmission of packet between given nodes using AntNet protocol. Whereas, Fig. 9(c) represents the network initialization phase for the scenario of star topology with one static node and nineteen mobile nodes where communication within network is initialized by nodes one to seven and fifteen to twenty. However, Fig. 9(d) represents the throughput computation between given nodes for star topology.

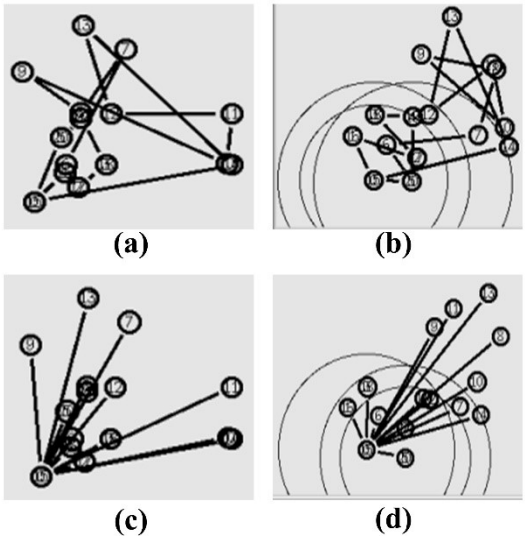


Figure 9: BeeIP Simulation for throughput computation using ring and star topology with 20 nodes

Figure 10(a) exhibits the delay for the network models comprising of 20, 50, and 100 nodes arranged in Ring topology. As it can be seen clearly, that while 20 nodes are communicating AntNet has lesser delay as compared to BeeIP protocol.

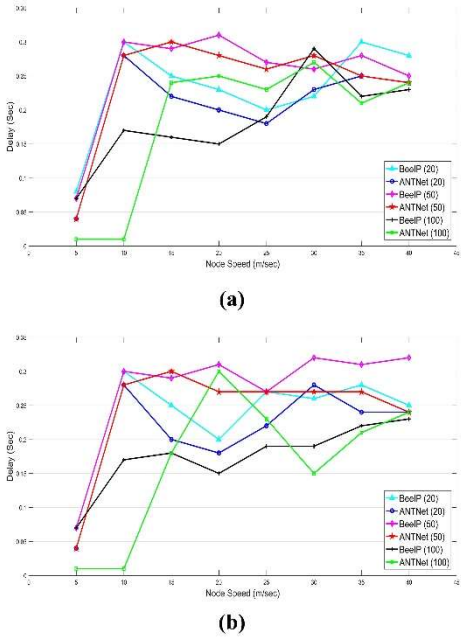


Figure 10: Delay Graph (a) Ring Topology (b) Star Topology

A similar behavior is observed in case of 50 nodes, that is while 50 nodes are communicating AntNet has lesser delay as compared to BeeIP protocol. However, with large no. of nodes that is 100, BeeIP shows lesser delay as compared to the AntNet and it can be seen very clearly in the graph shown in Fig. 10(a).

Figure 10(b) shows the end-to-end delay for the network models comprising of 20, 50, and 100 nodes arranged in star topology. The graph in Fig. 10(b) shows that with greater number of nodes BeeIP shows lesser delay. However, in case of less no. of nodes (20 and 50) AntNet indicates the lesser end-to-end delay for the nodes arranged in star topology.

Conclusively, End-to-End Delay of AntNet is smaller as compared to BeeIP routing protocol but the only drawback with AntNet protocol is that it takes more time to initialize nodes while number of nodes are more than 50.

Figure 11(a) exhibits the throughput for the network scenarios comprising of 20, 50, and 100 nodes arranged in Ring topology. It is very much obvious that the throughput of the network with 20 and 50 nodes placed in a ring topology, attains a better throughput when communicate using AntNet protocol as compared to BeeIP protocol.

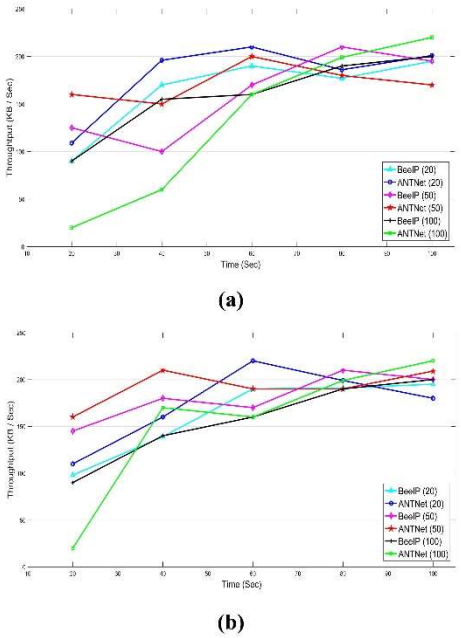


Figure 11: Throughput Graph (a) Ring Topology (b) Star Topology

Although, in case of 100 nodes AntNet experiences a better throughput but in parallel initialization of the nodes using AntNet consumes more time when compared with that of the BeeIP protocol

A similar behavior is observed for the network models with 20, 50, and 100 nodes arranged in star

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topology. It can be seen clearly from the graph shown in Fig. 11(b) that still a better throughput of the network is obtained while communicating using AntNet protocol among the network models designed with 20, 50, and 100 nodes.

Experimental results show that the no. of packets received in a unit time are greater when AntNet protocol is used for communication regardless of the no. of nodes. Besides, BeeIP exhibits reduced throughput comparatively. However, one limitation is observed that when the no. of nodes is increased more time is required by AntNet to initialize the nodes. Moreover, BeeIP protocol shows a smaller communication overhead as compared to that of the AntNet protocol as depicted by Fig. 12.

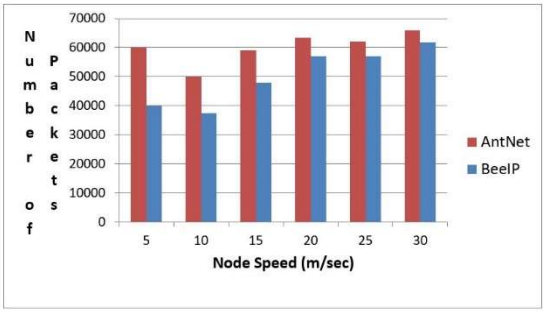

Figure 12: Communication overhead in AntNet and BeeIP

5. CONCLUSION

This study has presented a comparative analysis of the two Swarm intelligence-based routing algorithms, AntNet and BeeIP. Both algorithms have been tested using NS-2 simulator with varying parameters for different no. of nodes using ring and star topologies. It has been concluded from experimental work that BeeIP has smaller communication overhead as compared to AntNet. However, AntNet is a suitable routing algorithm for solving the routing problem in mobile ad-hoc networks. AntNet is self-built and self-configured optimization algorithm that matches the characteristics of ad-hoc networks. Although AntNet protocol takes time to route packets when number of nodes are greater than or equal to100 but overall performance of AntNet protocol is better than BeeIP protocol.

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