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Bee-MANET: A New Swarm-based Routing Protocol for Wireless Ad Hoc Networks

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***Abstract*—Recently, mobile ad hoc networks (MANETs) have drawn attention by many researchers due to the development of portable devices and wireless network appliances have accounted for ad hoc networks. Many academic researchers have shown great interest in ad hoc networks for twenty years. One of the main fields adopted by researchers studying on Mobile Ad-hoc Networks is to develop routing protocols in wireless systems. Routing protocol development is related to complexity, scalability, adaptability, productivity, and battery life in wireless systems. Routing protocols for wireless systems are developed in order to cope with these problems. In this paper, a new routing protocol for mobile ad hoc network (Bee-MANET) was presented to improve network throughput. Bee-MANET, AODV and Beeadhoc routing algorithms for MANETs are empirically compared in order to research their large-scale behaviors. The results presented as graphs and brief discussion is given.**

***Index Terms*—Mobile Ad-Hoc networks, Ns-2, routing protocols, swarm intelligence, simulation.**

I. INTRODUCTION

Today rapidly developing Internet significantly relies on mobile or wireless (IEEE 802.11a/b/g) technologies, which allow easily and low cost expansion for the Internet coverage [1]. The development of communication technology has made wireless equipment less, more powerful and less expensive. Such rapid technology improvement has contributed great growth to mobile devices connected to the Internet [2]. Ad hoc mobile network is a multi-hop temporarily autonomous system of mobile nodes with wireless transmitters and receivers which does not have a pre-existing infrastructure, every node in the network takes parts in routing by forwarding the packets to others [3]. Therefore, routing infrastructure is dynamically determined on the basis of network connectivity. Nodes communicate with each other without any center authority in ad hoc networks and have a constantly changing network topology. Routing protocols are used to obtain the routes between the source nodes and destination nodes [4]. Due to the frequently changing network topology, mobile ad hoc networks utilize diverse routing protocols from other wireless systems. Frequently changing network topology causes constantly updating of routing tables and thus increases the number of control packets. The main part of every routing protocol is the routing protocol, which specifies all the logical processes of routing. In this process network traffic should not increase and should lose lesser number of packets, delay and battery life. Wireless mobile ad hoc networks are used to provide communication in case of war and natural disasters such as earthquakes and flood.

In MANET's, the growth of the number of nodes demands design and development of novel and intelligent routing protocols that would result in an intelligent and knowledgeable network layer [5]. Currently, the network layer is related to only switching data packets to the next hop based on the information in the routing tables collected by non-intelligent control packets. The new protocols, however, have to be designed with a careful engineering vision in order to improve network throughputs and scalability. Scalability is the capability of a routing protocol to carry out adequately as one or more parameters of the network increase to be large in value. Due to large amount of routing information in large ad hoc networks, routing must be done with less computing cost and as fast as possible. For routing in a network to be applicable, scalability is a significant feature for ad hoc routing protocols. At the present time, mobile ad hoc routing protocols are used in academic resources and industry. Many routing protocols are developed by researchers such as ABR, SSR, DSDV, CGSR, WRP, OLSR, Beeadhoc, AODV, ZRP, TORA, AntNet, HOPNET and DSR.

In this paper, Bee-MANET, AODV, and Beeadhoc algorithms are empirically compared to research large-scale behavior. The results were presented as graphs and were evaluated.

The rest of the paper is organized as follows: in Section II, we will review bees, wireless networks and ns-2 network simulator. Section III contains MANET routing protocols. Section IV is about proposed routing protocol. Section V, contains ns-2 simulation framework for protocol and finally Section VI concludes the paper.

II. BACKGROUND

A. Honeybees

In this research, we selected honeybees as typically real social insects. Honeybees are one of the examples of insect

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societies in which direct and indirect communication among workers provide cooperation in collecting nectar. Interactions between individuals in a beehive of a honeybee colony and reinforcement learning schemes have been well documented in [21]. Honeybees learn about their environment for their life long. When any worker has learned and remembered information about food, it transmits this information to other bees in the hive by means of a set of signals and cues [20].

Foraging behavior in honeybees is good example for self-organization. Honeybee colony must discover nectar regions and exploit them in an efficient way. When a honeybee forages for nectar within an environment with highly variable conditions, learning becomes important for hive productivity. Honeybees employ a trial and error learning approach in their foraging activity [21]. In a decentralized and parallel way, each bee obeys a set of simple rules based on some metrics (e.g. nectar concentration, location of the source, travel time to the source, etc.). All of the metrics that includes inner parameters (number of food storer bees) in the hive determine profitability of a nectar source. If colony encounters with more than one sources of nectar, highest profitable source is preferred by foragers relative to other source with less profitability [22]. Most well-known model was developed by Seeley in 1991.

In the foraging, honeybees use positive and negative feedback mechanisms to adjust their capacities to varying sources. These feedback mechanisms allows colony to be adaptive against to changes in environmental conditions. Positive feedback from scouts to uncommitted bees in the hive causes to increase exploitation of profitable sources. For example, if a scout discovers a rich nectar source, she recruits unemployed bees via waggle dance. Positive feedback in honeybees includes recruitment and reinforcement. Negative feedback balances positive feedback and helps to emerge collective pattern. It occurs in case of saturation, exhaustion and competition. For example, a forager flying to exhausted nectar source will not return to that source. Main phases of the honeybees in their life: traveling from the nest to the source, scouting for nectar, collecting nectar from the source, returning back to hive, transmitting the information to other bees and response to bee that spreads the information in the hive [21].

B. *Wireless Networks*

Wireless network is a type of network in which communication devices communicate with each other without any physical cable of equipment. In this way, wiring is not used to get communication between telecommunication equipment. It reduces the difficulty and cost of network installation. Radio waves are used in wireless communications networks. This implementation is located at the physical level of the network structure [6], [7].

There are two wireless networks: infrastructure wireless networks and mobile ad hoc networks. In infrastructure wireless networks, there is a base station for wireless devices to communicate with each other. Mobile ad hoc networks [4], [8]–[10] are self-organized and have dynamically changing networks topologies. All mobile nodes in mobile ad hoc networks can communicate with each other without any established centralized devices. The network topology may change frequently due to the node movements.

Routing in a mobile ad hoc network is exceptionally difficult on account of its dynamic structure. It has restricted bandwidth and battery power. The continuous movement of nodes will cause the network topology often change. Thus, the well routes will likely be unavailable in a short time. This would result in route updates for each node causes many control packets to flood through the network, consuming precious network resources. In a result, finding and maintaining a path in mobile ad hoc networks is not easy [11].

C. *The Ns-2 Network Simulator*

The ns-2 [12] network simulator is one of the most popular open source network simulators among academics. The ns-2 is the second version of ns network simulator. It was firstly developed by researchers of University of California Berkely. The first version of ns simulator was developed in 1989 and has improved by many researchers since then. The second version ns-2 is commonly used in academic research. The ns-2 is an object oriented and discrete event network simulator. It uses is C++ and OTcl programming language.

The network simulator ns-2 supports modeling, simulation and visualization of the fallowing network technologies and functionaries [13]:

1) Terrestrial, satellite and wireless networks with various routing algorithms (e.g. DV, LS, PIM-DM, PIM-SM, AODV, and DSR);
2) Traffic sources such as web, FTP, Telnet and CBR;
3) Failures, including deterministic, probabilistic loss and link failure;
4) Various queuing Packet flow, queue disciplines (e.g. DropTail, RED, FQ, SFQ and DRR) and QoS (e.g. IntServ and Diffserv), build up, and packet drop;
5) Protocol behavior: TCP slow start, self-clocking, congestion control, fast retransmit and recovery;
6) Node movement in wireless networks;
7) Annotations to highlight important events;
8) Protocol state (e.g. TCP congestion window);
9) Traffic and topology generation.

III. RELATED WORK

Many routing protocols have been proposed for ad hoc networks [2], [7], [10], [14]–[19]. These routing protocols can be divided basically into two types: table-driven and on-demand. In table driven routing protocols, each node has one or more tables to include routing information for all nodes in the network. A change in the network causes updates routing tables of all nodes. On-demand routing protocols, unlike the table-driven routing protocols, there is no requirement to keep continuously the routing tables for the nodes. Paths are only created when necessary. The generated paths are kept until packet reaches the destination node or certain period of time [16].

A. *On-Demand Distance Vector Routing Protocols*

Recently, on-demand routing protocols for ad-hoc networks are demanded because of their low routing overheads and effectiveness in the case of the frequency of route re-establishment and the demand of route queries are not high. In on-demand routing protocols, routes are created only when desired by the source node. Many on-demand routing protocols have been suggested in [2], [16], [19]. High routing overheads usually have important impacts on performance in low-bandwidth wireless links. Therefore, the reactive on-demand routing algorithms where routing paths are established only when desired are the recent reliability in ad-hoc networks, such as the ad-hoc on-demand distance vector (AODV) routing protocol. In the AODV protocol, there is only a single path established during the transmission of the packet. Therefore, when the transmission route fails, data packets are simply dropped by nodes along the broken route.

B. *The Beeadhoc Routing Protocol*

Beeadhoc algorithm has been taken into consideration in the comparison as an energy efficient routing protocol. It is originated from foraging features of honey bees as mentioned in Section II.A [19]. The protocol has two types of honey bees which are named scouts and foragers. Scouts are designed to finds paths from source nodes to destination nodes in networks. Scouts are sent using the broadcasting principle to all the neighbors of a node. Each scout has an extending time to live timer in the network. In Beeadhoc routing protocol, a forager is the main worker. It gets a data packet from transport layer and then transmits it to the destination node. They are two types of foragers: latency and lifetime. The latency foragers pick up the latency information from the network. The lifetime foragers pick up the remaining battery capacity of the nodes they visit through the network. Honeybees usually are forced to go long distances to find food. The areas of foraging honeybee finds a source of food for notice to the other members of the colony and return to the hive after a while they start to fly around the other honeybees.

Honeybees are deaf, and therefore will not be able voice communications with each other. They establish communications with each other with different shapes. These shapes are called dances. This dance has source distance, direction, information about the quality and quantity of food available [20].

IV. BEE-MANET ROUTING PROTOCOL

Bee-MANET routing protocol, has been developed by bunching together of social behavior of the honeybees and, common directions of the communication networks. Bee-MANET routing protocol has the characteristics of optional routing protocol. It falls within the protocols based on intelligence of swarm of bees, since it has been inspired by the behaviors of honeybees for searching natural food. Bee-MANET is more dynamic, simple, productive, trustable, elastic and scalable unicast routing protocol. It has targeted to both increase data throughput which the nodes have transmitted, and, decreasing the number of control packets which have been transmitted in network by using the resources more effectively. The scout bees, which have fulfilled the duty of searching food that belongs to each hive in the colony of honey bees, have corresponded to control packets in communication networks (Table I).

TABLE I. THE ESTABLISHED RELATIONSHIPS BETWEEN HONEY BEES AND NETWORK SYSTEMS.

Bees	Network
Hives	Nodes
Nectar area	Network
Scout	Forward and Backward scouts, Accumulator
Foragers	Data packets
Dances	Routing tables

The scout bees that belong to each node are sent to nectar area for searching food, when there need for a food. The routing information, associated with the node, has been acquired by obtaining the information in nectar area by sending scout bees. Thus, it selects the most appropriate path, by evaluating paths related to targeted node. The scout bees obtain the information of the distance and the time delay, associated with the nodes they have visited. Thus, it has been determined the distances among the nodes and spread delays. When the scout bees have returned, this information is transferred with the dances, which they have made in the hive. The ‘worker bee’ concept corresponds to data packets in the communication networks. Data packets are chosen from the newest paths in the network, which they have the least delay. The scout bees carry not only the information belonging to the paths they have passed, but also the information which have come from the other nodes to the next node. The name of “accumulator scout bee” has been given to the scout bees which transfer this information. The main objective in using accumulator is to use network resources more productive by reducing the number of scout bees which have circulated in the network. This case provides the number of data packets which have been transmitted concurrently to increase to a considerable amount. There are three kinds of scout bee in the Bee-MANET routing protocol: forward scout, backward scout and the accumulator. Forward scout, when it has been asked to send a packet from any node in the network to another, a packet is sent to the neighbor nodes about this asking when the source node has created forward scout (Fig. 1). When the neighbor node has received such a packet, primarily, it controls whether the packet has visited before in order to avoid loops. If such a packet has visited to that node before, it discards the packet from the network. If this packet, which has come to the node, has reached to the target node, it is sent back from its coming path by creating backward scout to the source node. If the node is not a destination node, accumulator is created and forward scout is added to it. Accumulator kept waiting for a short while, it is waited another forward scout bees to come to the same node. If another forward scout bee comes, this forward scout bee also is added to the same accumulator. It is sent to the neighbor of the node, after a certain while. Accumulator has targeted sources being used more productively by reducing forward scout bees circulated in the network. Here, scout bee which has come to a node, primarily, after having it keep waiting for a short while (0.1 ms) in the created accumulator, it will be waited for scout bees to come for different targets from other nodes. When the time has expired, forward scout bee, which is within accumulator bee, is sent to network with its list. When the accumulator bee has come to the hive, primarily, it reaches to the list of accumulator scout bee (Fig. 2). By getting scout bees out here to eject one by one, it is provided to carry out the routing operations which the scout bees had to do in the hive.

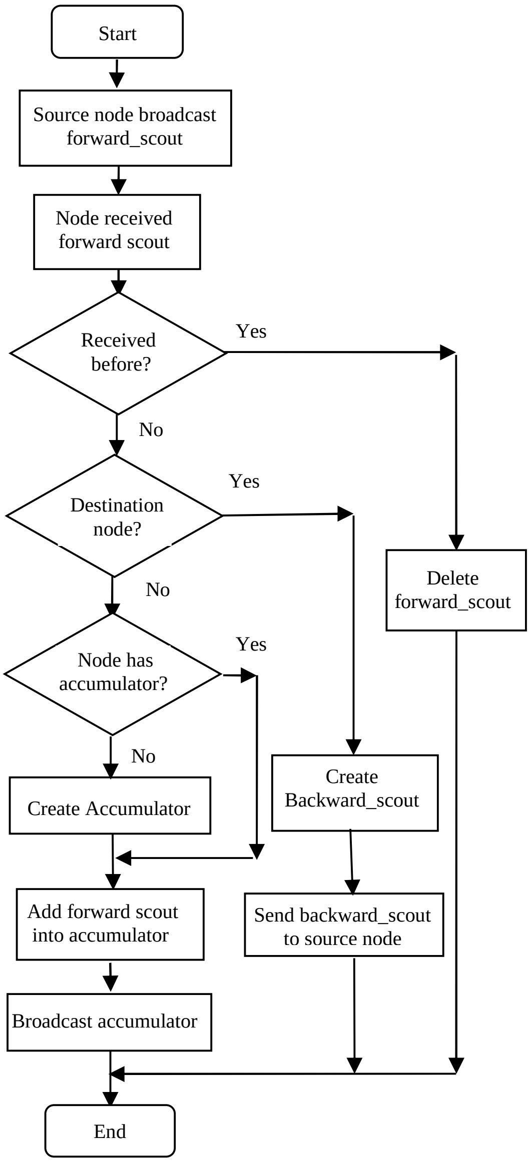

Fig. 1. Hive received forward_scout.

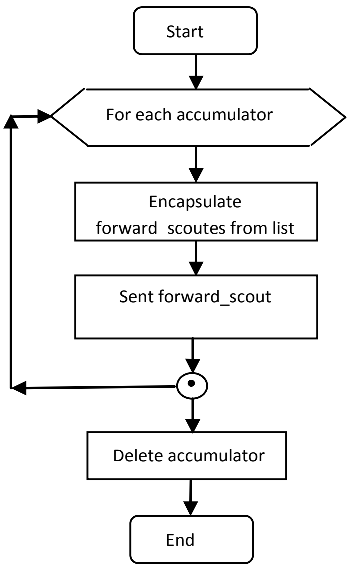

Fig. 2. Hive received accumulator.

After all the scout bees in the list have been extracted, accumulator has fulfilled its duty and is removed from the hive in order not to occupy a place.

V. NS-2 SIMULATION FRAMEWORK FOR PROTOCOL COMPARISON

A. Simulation Parameters

We evaluated the performance of Bee-MANET, AODV and Beeadhoc in ns-2 simulator to measure their effective in particular for large networks. Our test scenarios are built with setdest.exe and cbrgen.tcl scripts used in ns2. Traffic and scenario files are independent directory in ns-2 network simulator. They are named *cbr* and *senario* respectively. Traffic file is generated by using "cbrgen.tcl" script which is in the folder "cmu-scen-gen/" in ns-2. Setdest.exe script is used to define number and velocity of nodes in network. Setdest file is generated by using "setdest.exe" which is in the folder "cmu-scen-gen/setdest" in ns-2. The cbr and scenario files are created by using the following commands [9], [11]:

```
ns cbrgen.tcl -type traffic] [-nn numberofnodes] [-seed seed] [-mc maxconnections] [-rate rate].
./setdest -n <numofnodes> -pause -s <maxvelocity> -t <simutime> -x <maxi> -y <maxi>
```

All configurations are same for Bee-MANET, AODV and Beeadhoc. These protocols are issued together with ns-2 simulator.

Simulation-based analysis and comparison established under the ns-2 network simulator. Under the ns-2 simulator, all protocols were executed with same traffic, environmental conditions and the results are presented in graphs. Thus, with the help of simulation-based performance analysis, protocol aspects such as scalability and efficiency are evaluated.

Table II shows the simulation parameters used in the process for comparison. In this study, we developed models having following node movement speeds: a minimum speed of 1 m/s (walking speed), 5 m/s (running speed) and 10 m/s (vehicle speed). Number of the nodes was chosen as 10, 100 and 200. The maximum number of nodes used here is closely related to the computer's configuration and performance.

TABLE II. SIMULATION PARAMETERS.

Parameter	**Value**	
Topography	Number of nodes	Area (m^2)
	10	300 x 300
	100	700 x 700
	200	1500 x 1500
Mobility (m/s)	1, 5, 10	
Packet Size (bytes)	512	
Topology generator	SETDEST	
Traffic generator	CBRGEN	
Traffic	FTP/TCP	
Simulation time (s)	50	
Computer	i7 , 6 GB RAM	
Operating system	Fedora 6	

In the experiments, scale of the simulation model in ns-2 was selected up to 200 nodes since larger models have caused memory overflow error. Though ns-2 supports large-scale models, the scale highly depends on the computer configuration. The number of node is proportional to the size of network topology.

Topology scenarios are created with the script setdest.exe and traffic scenarios are created with the script cbrgen.tcl which found in the ns-2 network simulator. TCP and FTP applications are used for all nodes. The data packet size is set to 512 bytes for all simulations. In all protocols and scenarios the simulation period is limited to 50 seconds. All other parameters are set equal for all scenarios.

B. Performance Metrics

In this section, two different metrics are used for evaluating the performance of Bee-MANET as well as AODV and BeeAdhoc. Throughputs and average end-to-end delay are compared at different speed and different size of nodes. Throughput of the routing protocol means that traffic packets received in certain time of simulation for any node in a network. The unit of throughput is megabyte per second (Mbps). Average end-to-end delay includes all possible delay while transmitting the date packet from source node to destination nodes. Hence

$$\text{Delay} = (\text{Time\_Receive} - \text{Time\_Sent}). \tag{1}$$

C. Simulation Results

Through this section, throughput and end-to-end delay of Bee-MANET, AODV and Beeadhoc routing protocols are compared at the different speed and in different number of nodes.

Experiment 1: Throughput

In this experiment, the nodes have moved during the simulation, in Fig. 3, Fig. 4 and Fig. 5, for 10 nodes at maximum speeds of 1 m/s, 5 m/s and 10 m/s.

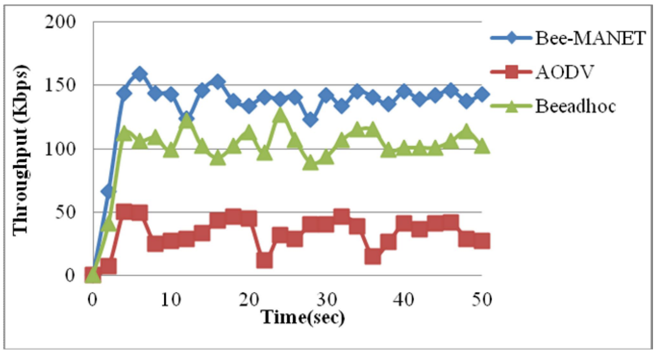

Fig. 3. Throughput of ten nodes at speed of 1 (m/s).

In Fig. 3, it has seen that Bee-MANET protocol has transmitted more packets uninterruptedly, during the simulation, for 10 nodes and maximum 1 m/s node motion. This means Bee-MANET processes more bits per seconds and yields less packet loss in slow movements.

In Fig. 4, for 10 nodes and maximum 5 m/s node motion; it has been seen that Bee-MANET protocol has transmitted more packets during the simulation till 15 seconds. After that time, three protocols have almost same average throughput value in the same traffic conditions. The reason is that Bee-MANET protocol has a fast response to traffic surges due for its light-weight control packet infrastructure.

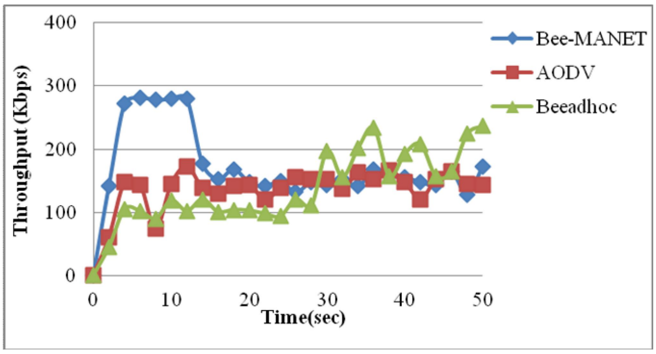

Fig. 4. Throughput of ten nodes at speed of 5 (m/s).

In Fig. 5, for 10 nodes and maximum 10 m/s node motion, while Bee-MANET and AODV protocols have transmitted packets close to each other. In a very high speed movements of the nodes, average throughput is highest of the developed protocol with consistent to outcomes of the Fig. 3.

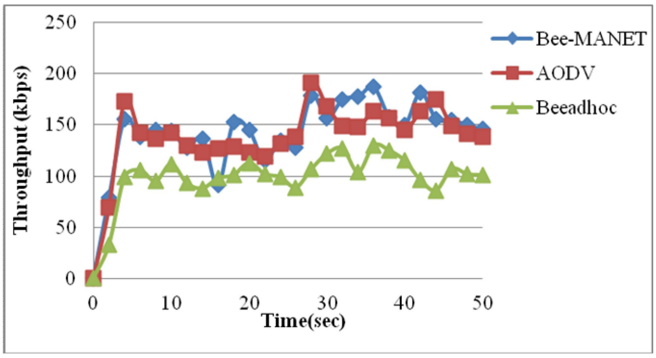

Fig. 5. Throughput of ten nodes at speed of 10 (m/s).

In Fig. 6, for 100 nodes and maximum 1 m/s node motion, Bee-MANET protocol has transmitted max packet. Here, it has seen that BeeAdhoc protocol has transmitted more packets than AODV protocol and given better throughput. The developed protocols' less control packet overhead and its accumulator approach gives very good performance against state of the art protocols.

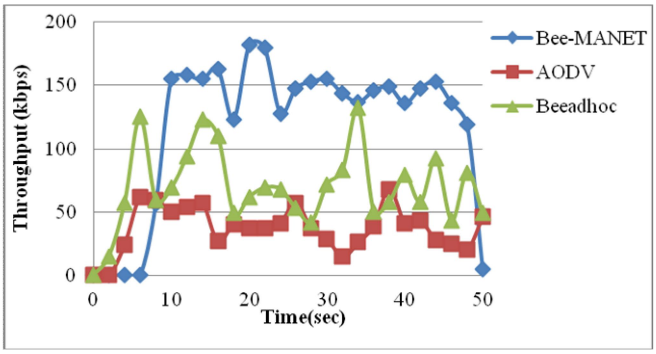

Fig. 6. Throughput of hundred nodes at speed of 1 (m/s).

In Fig. 7, 100 nodes and maximum 5 m/s node motion, although Bee-MANET protocol has transmitted max packet, it has seen that it has not transmitted packet at the 18^{th} seconds. It has been seen that in the range of 10 - 25 second, AODV protocol has transmitted more packets. The average value of the throughput is better than BeeAdhoc and AODV. The main reason is that since protocol has better response and runs speedy manner, in the connection intervals, nodes transmit more data than the other protocols and this fact yields better throughput.

In Fig. 8, for 100 nodes and max 10 m/s node motion, Bee-MANET protocol has transmitted max packet even if interruptedly. Here, it has been seen that BeeAdhoc and AODV could not transmit packets throughout simulation. Higher speeds seems very problematic for AODV and BeeAdhoc. Though very high speeds, developed protocol remains survavibility.

In Fig. 9, for 200 nodes and max 1 m/s node motion, it has been seen that Bee-MANET protocol has transmitted more packets uninterruptedly during simulation. Here, it has seen that BeeAdhoc protocol could not transmit packets in the range of the 25th and 30th seconds.

In Fig. 10, for 200 nodes and max 5 m/s node motion, it has seen that Bee-MANET protocol could transmit more packets and uninterruptedly. Here, it has seen that AODV could not transmit packet in the 25th second.

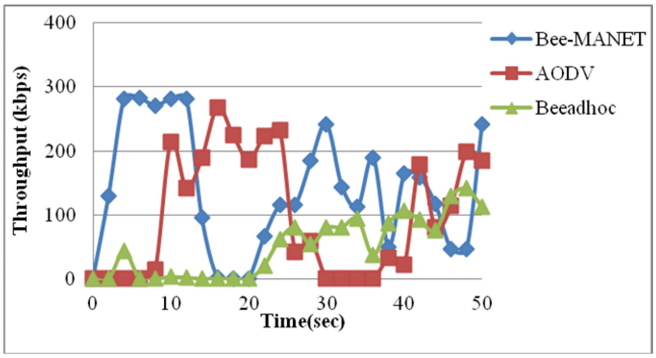

Fig. 7. Throughput of hundred nodes at speed of 5 (m/s).

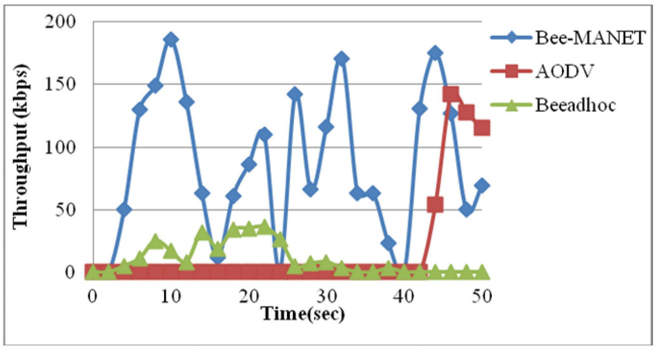

Fig. 8. Throughput of hundred nodes at speed of 10 (m/s).

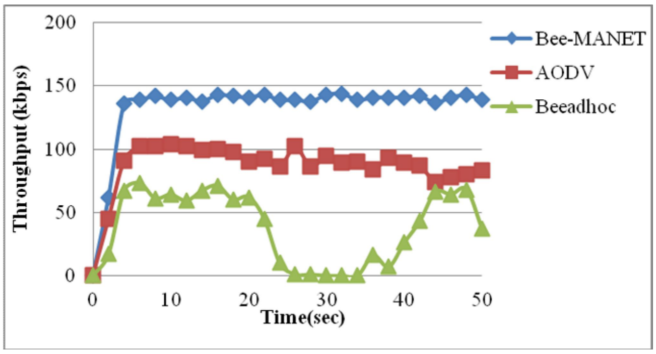

Fig. 9. Throughput of two hundred nodes at speed of 1 (m/s).

When we have evaluated all the throughput results of the simulation, it has seen that, Bee-MANET protocol, in all cases, has transmitted more packets than AODV and BeeAdhoc protocols and therefore yields better performance. As already mentioned, operation of combining control packets circulating for different targets in the network called accumulation process decreases the traffic overhead of control packets and simple design of the control packets increases the performance the whole network. Therefore Bee-MANET protocol has better response, low packet-loss and higher goodput.

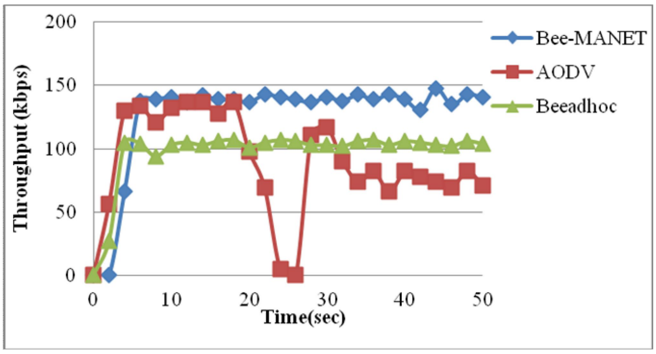

Fig. 10. Throughput of two hundred nodes at speed of 5 (m/s).

Experiment 2: Average End-to-End Delay

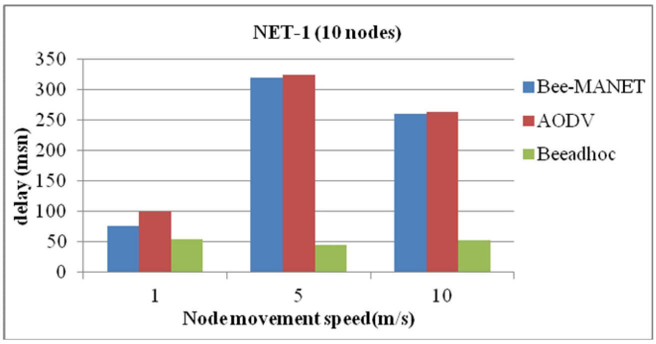

Fig. 11. End to end delay of ten nodes.

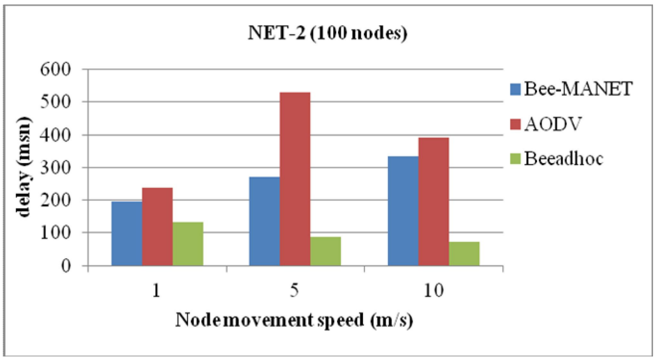

Fig. 12. End to end delay of hundred nodes.

We measured the end-to-end delays of the three protocols. Fig. 11 and Fig. 12 depict the results. As shown in the figures, BeeAdhoc protocol consistently gives the lowest but the best delay value. Though Bee-MANET and AODV protocols yield almost same delay values, developed protocol provides one-step better delay when transmitting the packets. Due for packets wait in a node for being accumulated with similar packets, delay performance of the developed protocol is not the best but better than AODV.

VI. Conclusions

In this paper, a new routing protocol for Ad Hoc networks has been developed by inspired swarm intelligence of the honeybees. Developed protocol called Bee-MANET has been compared to BeeAdhoc and AODV protocols which are most known protocols in the network community. Results show that Bee-MANET protocol, in low speeds (1 m/s), has given better throughputs. While speed and number of nodes increase, throughput values have surged but average value is higher than the other protocols. For example, for large scale networks, Beeadhoc has not given any throughput till 20 seconds (see Fig. 7). In large networks with higher speed, Bee-MANET gives significantly better throughput values but poorer delay than BeeAdhoc protocol (see Fig. 8). At the end of the comparisons, it has been seen that when the amount of packet transmission considered, Bee-MANET has succeeded more than AODV and BeeAdhoc protocols, and its end-to-end delay performance is in the reasonable ranges.

The accumulator which has been used in the Bee-MANET protocol has provided the resources to be used further for packet transmission by reducing network traffic.

End to end delay of the Bee-MANET protocol is in the comparable level of the other protocols. For example, for ten nodes with low node movement speeds, Bee-MANET has better value from AODV but worse than BeeAdHoc protocol (see Fig. 11). While number of nodes increases, ranking in end-to-end delay performance of the protocols is preserved. Consequently, in this research, it has been understood that the methods for searching food inspired from honeybees, which are intelligent biologic leaving creatures, have desired properties for wireless ad-hoc networks.

REFERENCES

[1] A. Statkus, S. Paulikas, "Improving TCP Performance in IEEE 802.11Networks", *Elektronika ir Elektrotechnika (Electronics and Electrical Engineering)*, vol. 19, no. 5, pp. 99–102, 2013. [Online]. Available: http://dx.doi.org/10.5755/j01.eee.19.5.2571

[2] K. W. Lai, S. Hsiao, Y. Lin, "Adaptive backup routing for ad-hoc networks", *Computer Communications*, vol. 30, no. 2, pp. 453–464, 2006. [Online]. Available: http://dx.doi.org/10.1016/j.comcom.2006.09.011

[3] Y. Fu, Q. Liu, "Research of QoS Routing Algorithm in Ad Hoc Networks based on Reinforcement Learning", *Elektronika ir Elektrotechnika (Electronics and Electrical Engineering)*, vol. 19, no. 2, pp. 65–68, 2013. [Online]. Available: http://dx.doi.org/ 10.5755/ j01.eee.19.2.3472

[4] J. Marker, M. Corson, *Internet Engineering Task Force (IETF) Mobile Ad-Hoc Networks (MANET) Working Group Charter,* [Online]. Available: http://www.ietf.org/html.charters/manet-charter.html

[5] CH. V. Raghavendran, G. Naga Satish, P. Suresh Varma. "Intelligent Routing Techniques for Mobile Ad hoc Networks using Swarm Intelligence", *Int. Journal of Intelligent Systems and Applications (IJISA)* vol. 5, no. 1, pp. 81–89, 2012. [Online]. Available: http://dx.doi.org/10.5815/ijisa.2013.01.08

[6] J. Wang, E. Osagie, P. T. Ruppa, K. Thulasiram, *Hopnet: A hybrid ant colony optimization routing algorithm for mobile ad hoc networks.* Univercity of Manitoba, Canada, 2008.

[7] J. Jubin, J. D. Tornow, "The DARPA packet radio network protocols", in Proc. IEEE, vol. 75, no. 1, 1987, pp. 21–32. [Online]. Available: http://dx.doi.org/10.1109/PROC.1987.13702

[8] C. E. Perkins, "*Ad Hoc Networking, Addison Wesley (2001).and RSSI information"*, IEICE E88-B (9), pp. 3588–3597, 2005.

[9] L. Cikovskis, S. Vdovins, I. Slaidins, "Multipath Routing with Adaptive Carrier Sense for Video Applications in Wireless Ad-hoc Networks", *Elektronika ir Elektrotechnika (Electronics and Electrical Engineering)*, no. 6, pp. 37–42, 2011.

[10] U. Kulkarni, D. Sachin, G. Swapnil, "Survey of Swarm Intelligence Inspired Routing Algorithms and Mobile Ad-Hoc Network Routing Protocols", *Int. Journal of Advancements in Research & Technology*, vol. 2, no. 9, pp. 146–152, Sept. 2013

[11] S. Upadhayaya, C. Gandhi, "Quality Of Service Routing In Mobile Ad Hoc Networks Using Location And Energy Parameters", *Int. Journal of Wireless & Mobile Networks (IJWMN)*, vol. 1, no. 2, Nov. 2009.

[12] Marc Greis, *Tutorial on ns2*. [Online]. Available: www.isi.edu/nsnam/ns/tutorial

[13] A. Zengin, "Large-Scale Integreted Network System Simulation with DEVS-Suite", *KSII Trans. Internet Information Systems*, vol. 4, pp. 452–474, 2010.

[14] C. E. Perkins, E. Royer, "Ad hoc on-demand distance vector routing", *in Proc. IEEE WMCSA*, 1999.

[15] C. E. Perkins, P. Bhagwat, "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers", in *Proc. ACM SIGCOMM,* 1994, pp. 234–244.

[16] C. E. Perkins, S. Royer, S. Das, "Ad Hoc On-Demand Distance Vector (AODV) Routing", *Internet Draft*, Feb. 2003, [Online]. Available: draft-ietf-manet-aodv-13.txt

[17] R. Dube, C. D. Rais, K. Wang, S. K. Tripathi, "Signal stability based adaptive routing (SSR alt SSA) for ad hoc mobile networks", *IEEE Personal Communication*, 1997.

[18] C.E. Perkins, P. Bhagwat, "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers", in *Proc. ACM SIGCOMM*, 1994, pp. 234–244.

[19] H. F. Wedde, M. Farooq, *The wisdom of the hive applied to Mobile Ad Hoc Networks*, University of Dortmund, 2005.

[20] K. Frisch, *The Dance Language and Orientation of Honey bees*, Cambridge: Harvard University Press, 1967.

[21] T. D. Seely, *The Wisdom of the Hive*. Cambridge, Mass: Harvard University Press, 1995.

[22] G. Alexandros, M. S. Wilson, "Swarm intelligence to wireless ad hoc networks: adaptive honeybee foraging during communication sessions", *Adaptive Behavior,* vol. 21, pp. 501–515, 2013. [Online]. Available: http://dx.doi.org/10.1177/1059712313500797