AntNet-RSLR: A Proposed Ant Routing Protocol for MANETs

Ahmed. A. A. Radwan[1]
Dept. of Computer Science
Dean of Faculty of Computers and Information Minia University
El Minia - Egypt
aaaradwan2008@yahoo.com

Tarek. M. Mahmoud[2]
Dept. of Computer Science
Faculty of Science
Minia University
El Minia - Egypt
tarek@minia.edu.eg

Essam. H. Hussein[3]
Dept. of Computer Science
Faculty of Computers and Informatics
Benha University
Benha - Egypt
esam.halim@fci.bu.edu.eg

Abstract: **A mobile ad hoc networks (MANETs) is a dynamic mobile wireless network that can be formed without the need for any pre-existing wired or wireless infrastructure. One of the main challenges in an ad hoc network is the design of robust routing algorithms that adapt to the frequent and randomly changing network topology. This paper proposes a novel routing scheme for MANETs, which adapts the AntNet protocol with the blocking-expanding Ring Search and Local Retransmission technique (AntNet-RSLR). According to this protocol, a group of mobile agents build paths between pair of nodes, exploring the network concurrently and exchanging obtained information to update the routing tables that decreases both of the routing message overhead and the average end to end delay less than the well known AntNet, AODV and DSR routing protocols. This led to increase the throughput more than AntNet, AODV and DSR routing protocols. AntNet-RSLR has been implemented using NS-2 simulator.**

Keywords: MANETs, Routing Protocol, ACO, AODV, DSR, AntNet, AntNet-RSLR.

I. INTRODUCTION

MANETs is a communication network of a set of mobile nodes, placed together in an ad hoc manner, without any fixed infrastructure that communicate with one another via wireless links. All nodes have routing capabilities and forward data packets for other nodes in multi-hop fashion. Nodes can enter or leave the network at any time, and may be mobile, so that the network topology continuously changes during deployment. Due to its dynamic nature, a primary challenge of MANET is the design of effective routing algorithm that can adapt its behavior to frequent and rapid changes in the MANET [8]. Ant Colony algorithm tends to provide properties such as adaptively and robustness, which are essential to deal with the challenges of MANETs

Generally three different types of routing protocols are available for MANET; they are proactive, reactive and hybrid routing protocol. In proactive routing protocol [9 and 25] all nodes are active and each node discovers a route to any other node in the network before the actual communication request. This leads to less time delay of route discovery during communication request. However, the overhead cost is too high in this case. DSDV [14 and 24] is an example of proactive routing protocol. On other hand, in reactive routing protocol [25] all nodes are in sleep mode. The nodes become active as and when they need to communicate with others. Therefore, it produces less overhead but requires more route set up time during communication. AODV [3, 5, 20, 21, 22 and 28] is an example of on-demand routing protocol. Hybrid routing protocol combines the advantages of both reactive and proactive routing protocols. ZRP [23] is an example of hybrid routing protocol.

Ant Colony Optimization (ACO) [4] is an example of Swarm Intelligence (SI) that can be applied to a wide range of different optimization problems, often giving better results. This is based on the study of ant colony behavior. In nature, ants collectively solve problems by cooperative efforts. Each individual ant performs a simple activity that has a random component. However, collectively ants manage to perform several complicated tasks with a high degree of consistency and adaptively.

ACO protocols for routing in MANET gather routing information through the repetitive sampling of possible paths between source and destination nodes using artificial ant packets. Ants are biologically blind and thus the communications between ants are indirect in which they sense and follow a chemical substance called pheromone. Pheromone attracts other ants and therefore ants tend to follow trails that have higher pheromone concentrations as more ants use that route and lay down more pheromone. As a result of this autocatalytic effect, the shortest path will emerge rapidly because a shorter path will have a higher pheromone concentration. After a while, the situation will converge where all other ants would follow only the trail which exudes the strongest scent indicating the best-possible route from the colony's nest (i.e. source) to the food source (i.e. destination end) [8 and 17]. The biological ant's problem solving paradigm can be used to solve routing problems in a MANET, by modeling an ant colony as a society of mobile agents. The ant based solutions for MANET routing are more appealing because they easily fit into the dynamic nature of MANET. We investigate the issue of adaptive routing in MANET, using ideas of ACO mechanisms along with other techniques of Artificial Intelligence (AI) to get a powerful protocol for the MANET. The AntNet-RSLR routing protocol combines ideas from ACO routing with Blocking-ERS and Local Retransmission techniques.

The rest of the paper is organized as follow; section 2 discusses related works of reactive and ant based routing protocols. New proposed routing protocol is discussed in section 3. Simulation environment is described in section 4 followed by performance evaluation parameters in section 5. Section 6 discusses the performance summary of the considered routing protocols followed by conclusions in section 7.

978-1-4577-0069-9/11/$26.00 ©2011 IEEE

II. Related Work

A. Ad Hoc On-Demand Distance Vector Routing (AODV)

AODV is a state-of-the-art routing protocol that adopts a purely reactive strategy: it sets up a route on-demand at the start of a communication session, and uses it till it breaks, after which a new route setup is initiated. AODV adopts a very different mechanism to maintain routing information. It uses traditional routing tables, one entry per destination [25 and 28]. Without source routing, AODV relies on routing table entries to propagate a route replay (RREP) back to the source and, subsequently, to route data packets to the destination. AODV uses sequence numbers maintained at each destination to determine freshness of routing information and to prevent routing loops. All routing packets carry these sequence numbers. An important feature of AODV is the maintenance of timer-based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. These nodes are notified with route error (RERR) packets when the next-hop link breaks. Each predecessor node, in turn, forwards the RERR to its own set of predecessors, thus effectively erasing all routes using the broken link. Route error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link.

B. Dynamic Source Routing (DSR)

The key distinguishing feature of the reactive protocol DSR [1, 25and 28] is the use of source routing. That is, the sender knows the complete hop-by-hop route to the destination. These routes are stored in a route cache; this is in contrast to AODV which uses traditional routing tables, one entry per destination. DSR can maintain multiple route cache entries for each destination. The data packets carry the source route in the packet header. When a node in the ad hoc network attempts to send a data packet to a destination for which it does not already know the route, it uses a route discovery process to dynamically determine such a route. Route discovery works by flooding the network with route request (RREQ) packets. Each node receiving an RREQ rebroadcasts it, unless it is the destination or it has a route to the destination in its route cache. Such a node replies to the RREQ with a route reply (RREP) packet that is routed back to the original source. RREQ and RREP packets are also source routed. The RREQ builds up the path traversed across the network. The RREP routes itself back to the source by traversing this path backward. The route carried back by the RREP packet is cached at the source for future use. If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source if this route is still needed. DSR makes very aggressive use of source routing and route caching.

C. Ant based routing protocols

The idea of ant algorithms derives from real swarms of certain insects, which develop a form of "swarm intelligence" and solve complex problems through cooperation [2, 13 and 26]. However, the colony at large shows a global intelligent behavior. Ants utilize a specialized form of communication, which is called *stigmergy* [5] in biology and means indirect communication through the environment. Overall, the ant-based solution for wireless ad hoc routing is more appealing because they easily fit into the dynamic nature of MANET. It provides adaptively, flexibility, robustness and even efficiency which are prime requisites in such environment. Here we discuss some examples of ant-based routing algorithm.

C.1 AntNet

AntNet [2, 7, 18 and 27] is a meta-heuristic ant based routing protocol in which, two types of routing agents have been used like forward ants and backward ants. At regular intervals, forward ants are launched towards randomly selected destination. The backward ant is generated after the forward ant reach at the destination point and to utilize useful information gathered by the forward ants. The backward ants inherit route information from the forward ant and use it to update the pheromone values in the node's routing tables as it travels back on the same path of the forward ant. The amount of pheromones deposit is dependent on the trip time of the forward ants. AntNet is slow in terms of end-to-end delay which is a main disadvantage.

C.2 ARA

ARA [19] is routing protocol based on AntNet and has similar operations in terms of route discovery. But in ARA, routes are maintained primarily by data packets as they flow through the network. The path to the destination is reinforced by increasing the pheromone value in the routing table as data packets travel along instead of using periodic ants like AntNet.

C.3 AntHocNet

AntHocNet [6] is a multipath routing algorithm for mobile MANETs that combine both proactive and reactive components. It is based on AntNet, with some modifications to be used on MANET.

C.4 Termite

This routing algorithm [10] adopts the analogy of termites instead of ants. Each network node is an analogy to a termite hill. The more termites passing through a node, the more pheromone would be collected at the node, making it a preferred next-hop node for other packets. There are five types of packets used in Termite. These are data, hello, RREQ, RREP and seed. Data packets are routed following the pheromones of each outgoing links. Each node will increase the pheromone of the previous node that the packet came from. There is no flooding involve in Termite. A limited number of RREQ packets perform a random walk over the network in search for the destination. The reply packet is routed by following the pheromone trail left by the request packet.

In this paper, we used and implemented the Blocking-ERS [11] and Local Retransmission concepts to improve the performance of proposed routing protocol. Further, AntNet, AODV and DSR routing protocols are used for comparison with the proposed AntNet-RSLR and performs better than the other considered routing protocols.

III. PROPOSED ROUTING PROTOCOL

The scalability problem can arise in large network if the destination node is close to source node. The request message that pass through each node in the network, can be extremely wasteful; especially if the destination node is relatively close to route request originator source node. Using the expanding ring search (ERS) method [12], the request message is flooded in the form of ring search, first in a smaller scale neighborhood with small time to live (TTL) value and it is incremented till destination is found. If the originating source node does not receive a reply within certain period of time, it rebroadcasts the request message with higher TTL value. This will be continuing till the route is discovered. The search is controlled by the maximum hop count field. If TTL values in the route request have reached a certain threshold, and still no request reply has been received, then destination node is assumed to be unreachable. However it consumes large routing overhead and it may end in the loop which leads to reduce the Packet Delivery Ratio. So the performance of routing protocol in form of efficiency and scalability decreases.

To improve the scalability and efficiency of routing protocol Blocking-ERS [11] can be used which is the extension of ERS. Blocking-ERS does not resume its route search procedure from the originating source node when a rebroadcast is required. The rebroadcast can be generated by any appropriate intermediate node instead of originating source node. The rebroadcast can be performed on behalf of the originating source node act as relay node. This technique is used to scale up the performance of proposed routing protocol. It also controls the delay and network load of routing protocol.

Local Retransmission technique is used to retransmit the data packet after receiving negative acknowledgement (NACK) from the receiver node. In this technique the failure or unsuccessful data packet is retransmitted from local intermediate node instead of originating source node [29].

In this section we discuss the adaptation of the AntNet routing protocol for MANET and describe the proposed AntNet-Ring Search and Local Retransmission (AntNet-RSLR). The packets used in the network can be divided into two classes like data packets and control packets. Data packets represent the information that the end-users exchange with each other. In ant-routing, data packets use the information stored at routing tables for traveling from the source to the destination node. AntNet-RSLR contains a special routing table, in which each destination is associated to all interfaces and each interface has a certain probability.

Control packets like forward ant (FANT) and a backward ant (BANT) are used to update the routing tables and distribute information about the traffic load in the network. Apart from the above control packets, the neighbor control packets are used to maintain a list of available nodes to which packets can be forwarded. The HELLO messages are broadcasted periodically from each node to all its neighbors. It is necessary to check if the ant has arrived or not, as the destination address will change at every visited node. Birth time of an ant is the time when the ant has been generated. Arrival time at the final destination is used to calculate the trip time.

In the route discovery phase new routes are created by FANT and BANT. A FANT is an agent which establishes the pheromone track to the source node. It gathers information about the state of network. In contrast, a BANT establishes the pheromone track to the destination node. BANTs use the collected information to adapt the routing tables on their path. The FANT is a small packet with a unique sequence number. Nodes are able to distinguish duplicate packets on the basis of the sequence number and the source address of the FANT. It creates a set of routing agents called FANT to search for the destination host. The source node would initiate a route discovery mechanism when a path to destination needs to be established. The source node would disseminate FANT to all its one-hop neighbors. While the destination is still not found, the neighbor would keep forwarding the FANTs to their own neighbors and so on. This process continues until a route to the destination is found using Blocking-ERS; otherwise it sends a reply message to the source node. To prevent cycles, each node stores recently forwarded route request in a buffer. A node which receives a FANT for the first time creates a record in its routing table which consists of destination address, next hop, and pheromone value. The node interprets the source address of the FANT as destination address of BANT, the address of the previous node as the next hop, and computes the pheromone value depending on the number of hops the FANT needs to reach the node. Then the node relays the FANT to its neighbors. Duplicate FANTs are identified through the unique sequence number and destroyed by the intermediate nodes. When the FANT reaches the destination node, the destination node extracts the information of the FANT and destroys it. Subsequently, it creates a BANT and sends it to the source node. When the sender receives the BANT from the destination node, the path is established and data packets can be sent. AntNet-RSLR ensures that routing paths are free from loops, and does not require extra overhead of sequence number to prevent loops. Nodes can recognize duplicate receipt of data packets, based on the source address and the sequence number.

In route maintenance phase, the routes need to be monitored and strengthened during the communication. Once the FANT and BANT have established the pheromone tracks for the source and destination nodes, subsequent data packets are used to maintain the path. But established paths do not keep their initial pheromone values forever.

The route failures handling is also an important concern, which is mainly due to node mobility in MANET. AntNet-RSLR recognizes a route failure through a missing acknowledgement. If a node gets a route error (RERR) message for a certain link, it deactivates this link by setting the pheromone value to 0. Then the node searches for an alternative link in its routing table. It sends the packet via this alternate path, if there exist one; otherwise the node informs its neighbors, to relay the packet. If the packet does not reach the destination, the source has to initiate a new route.

Further using the local retransmission technique the failure or unsuccessful data packet is retransmitted from intermediate node instead of originating source node. The data packet retransmits only after receiving negative acknowledgement (NACK) from the receiver node. This leads to improve the packet delivery ratio with minimum end-to-end delay. The proposed routing protocol AntNet-RSLR is based on metaheuristic swarm intelligence whose working principle is inspired by social insect behavior and on-demand feature of AODV. Further it uses the blocking-ERS, local retransmission to make the Ant-RSLR scalable, efficient and reliable.

IV. Simulation Model and Performance Metrics

A. Simulation Model

The AntNet-RSLR routing protocol proposed in this paper is compared with the conventional AntNet, AODV and DSR routing protocols. Network Simulator (NS-2) [15] is a discrete event simulator used to simulate these protocols. The latest version of NS-2 (NS-2.33) which can model and simulate multihop wireless MANETs was used for the simulations. The interface queue gives priority to routing packets in being served. The transmission range for each of the mobile nodes is set to 150m and the channel capacity is 2Mbps. Simulations were run for 600 simulated seconds.

A.1 Mobility Model

The simulation models a network of 100 and 200 mobile nodes migrating with rectangular area size *1500x1000m*^{2}. The mobility model uses the random waypoint (RWP) model in the rectangular field. In this, each node is randomly placed in the simulated area and remains stationary for a specified pause time. It then randomly chooses a destination and moves there at a velocity chosen uniformly between a minimum velocity and a maximum velocity. Each node independently repeats this movement pattern through the simulation. The simulations were run multiple times for different pause times seconds. Pause time is the dormant time during which the node does not move after reaching a destination. After pausing for pause time seconds it again selects a new destination.

A.2 Traffic Model

We chose our traffic sources to be constant bit rate (CBR) sources. When defining the parameters of the communication model. The number of source-destination pairs and the packet sending rate in each pair is varied to change the offered load in the network. We can use shell command. Cbrgen to generate 5 pair of, 10 pair of, 20 pair of, 25 pair of and 50 pair of UDP stream stochastically, thus, the network connectivity is 0.5. Each CBR package size is 512 bytes and one second transmits one package which used varying the number of CBR source was approximately equivalent to varying the sending rate. We have chosen this value because smaller payload sizes penalize protocols that append source routes to each data packet. The simulations have been carried using the parameters in Table 1.

TABLE 1: Scenario for NS-2 topology

Parameter	Value
Number of simulated nodes	100-200
Area size of topography x(m)	1500x1000m^2
Wireless range	150 m
Packet size	512 byte
Send rate of traffic	1 packets / s
Traffic type	CBR
Speed Mobility Model	RWP
Pause Time (s) at simulation	0, 30, 60, 120, 300 and 600 s
Simulation Time	600 s
Simulated Routing Protocols	AntNet-RSLR , AntNet, AODV, DSR

V. Simulation Results and Performance Analysis

This section presents performance comparison of the protocols, an attempt was to compare the four routing protocols under the same simulation environment, and we will try to discuss the behavior of the considered protocols dependence on continuous pausing time and variable network size.

A. Average End-to-End Delay analysis

EED for the considered routing protocols is shown in Figs. 1 and 2; the delay increases for all routing protocols until at pause time 300 and then decreased.

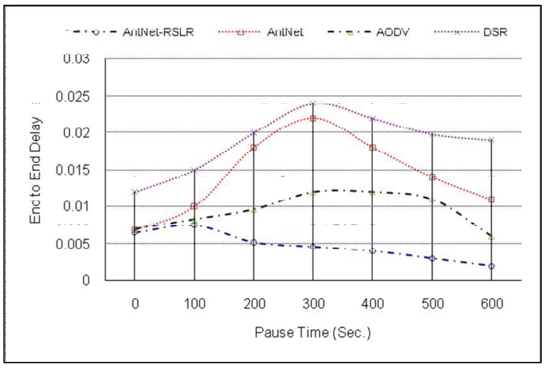

Figure 1: EED vs. Pause Time for 100 nodes

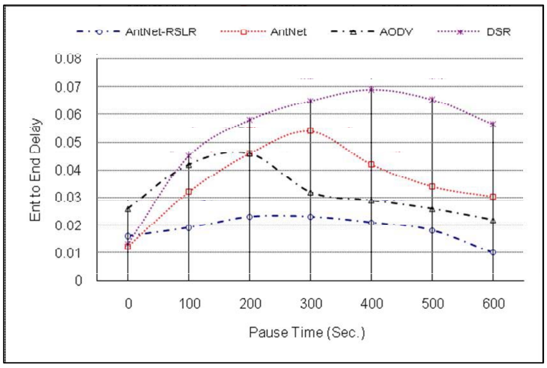

Figure 2: EED vs. Pause Time for 200 nodes

DSR show long delay than the considered routing protocols because when requesting a new route, DSR first searches the route cache storing routes information it has learned over the past routing discovery stage and has not used the timer threshold to restrict the stale information which may lead to a routing failure, moreover, DSR needs to put the routes information not only in the route reply message but also in the data packets which relatively make the data packets longer than before. Both of the two mechanisms make DSR to have a long delay than the other three protocols. The disadvantage of AntNet is that it is intrinsically slow since it requires the ant agent to reach the destination before any updates to the routing table this make AntNet to have a long delay this overcome in the proposed protocol by using blocking-ERS and local retransmission. AODV uses the source-initiated in the route discovery process, but at the route maintenance stage, it uses the way of the table-driven, which also shows the better delay characteristic. AODV exhibits a shorter delay because it is a kind of on-demand routing protocol, each node maintains a routing table in which all of the possible destinations with the network and the number of hops to each destination are recorded, only packets belonging to valid routes at the ending instant get through. The increase in the number of broken links in the protocols will lead to increase the delay of transferring packets on a route until finding a repair to the route. AntNet-RSLR has number of broken links lower than the other protocols. The EED given by AntNet-RSLR is reduced by blocking-ERS and local retransmission cause the resuming of route discovery process from where it left in the previous round following a failure to discover a route to the destination node.

B. *Normalized Routing Overhead analysis*

The considered routing protocols impose vastly different amounts of overhead, as shown in Figs. 3 and 4.

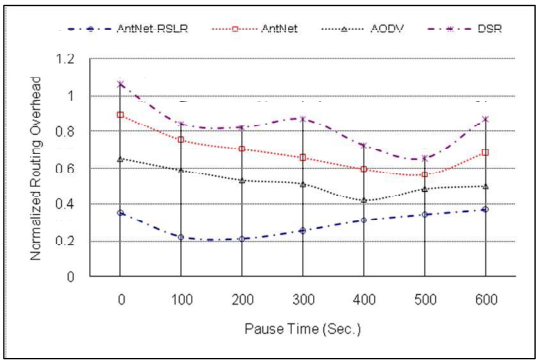

Figure 3: NRO vs. Pause Time for 100 nodes

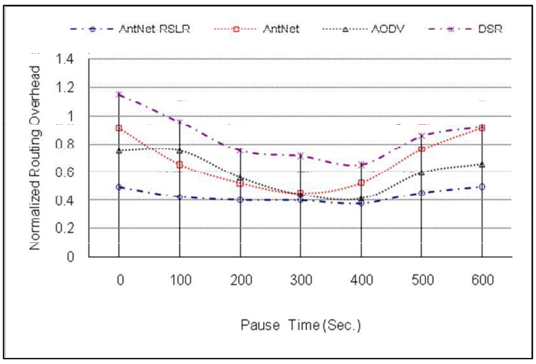

Figure 4: NRO vs. Pause Time for 200 nodes

NRO increases as the pause time increases, AntNet-RSLR gives overhead lower than the other protocols. But we notice that the value of the NRO tends to the highest value at the beginning of the simulation time and after that decreased for all considered routing protocols.

The results of the simulation show that AODV, DSR and AntNet impose a huge NRO compared with AntNet-RSLR. This is not surprising due to the extensive and regular updates of the routing tables at the nodes. In addition, DSR has a worse NRO than AODV. DSR needs to put the route information in the route reply message as well as in the data packets. AntNet-RSLR has lower NRO than the other routing protocols. This demonstrates the effect of blocking-ERS and local retransmission trials and especially as the network size grows up, where the trials of local retransmission reduce routing message overhead and by its turn free bandwidth channels and this led to transfer data packets faster. However DSR, which has the heaviest NRO than the other considered routing protocol, AntNet-RSLR which has the lightest.

C. *Throughput analysis*

The number of packets dropped or left wait for a route reduce the throughput. Figs. 5 and 6, demonstrates the throughput vs. the pause time for the considered routing protocols. The number of packets dropped or left wait for a route affected by the success of local retransmission in repairing a failed route, where the number of packets dropped or left wait reduced as the percentage of success local retransmission attempts increased. AntNet-RSLR has number of packets dropped or left waits for a route less than the considered routing protocol this mean the proposed protocol give a higher throughput over the considered routing protocols.

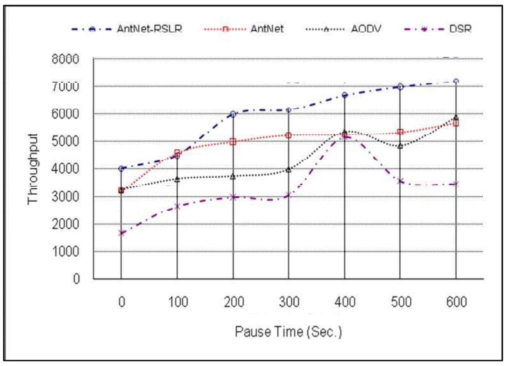

Figure 5: Throughput vs. Pause Time for 100 nodes

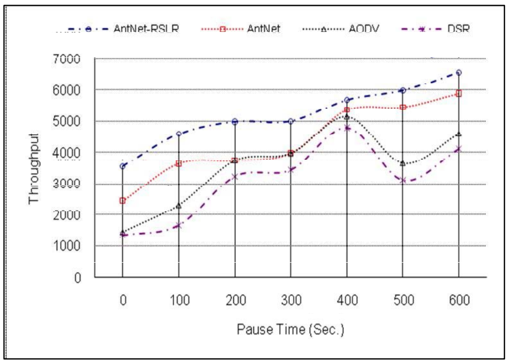

Figure 6: Throughput vs. Pause Time for 200 nodes

VI. PERFORMANCE SUMMARY

In this paper, blocking-ERS and local retransmission is used to improve the performance of AntNet. Improved packet delivery ratio denotes the efficiency, reliability and effectiveness of proposed routing protocol. Retransmission made from neighboring nodes of source node to destination instead of original source node. Thus, the NRO and EED are reduced by Blocking-ERS and local retransmission cause the resuming of route discovery process from where it left in the previous round following a failure to discover a route to the destination node. The general observation from our simulation:

- Average End to End Delay, EED of AntNet-RSLR is controlled through Blocking-ERS and local retransmission. From Figs. 1 and 2, it is observed that the EED of AntNet-RSLR is better than the other considered routing protocols.
- Normalized Routing Overhead, in real time application, NRO is one of the important parameter to measure performance of routing protocol. From Figs. 3 and 4, it can be concluded that, NRO for AntNet-RSLR is less than the other considered routing protocols.
- Throughput, Throughput is an indication of reliability, efficiency, and effectiveness of routing protocol. From Figs. 5 and 6, the throughput of AntNet-RSLR is more than the other considered routing protocols.

Finally, Table 2 summarizes the performance evaluation of the considered routing protocols mentioned in this paper. It provides correspondingly, the protocol name, the network size, and the performance matrices, where G, M and W mean Good, Medium and Worst performance respectively.

TABLE 2, SUMMARY OF PERFORMANCE RESULTS

Performance Matrices	**100 nodes**			
	AntNet-RSLR	**AntNet**	**AODV**	**DSR**
Normalized Routing Overhead	G	M	M	W
Average End-to-End Delay	G	M	M	W
Throughput	G	M	M	W
Performance Matrices	**200 nodes**			
	AntNet-RSLR	**AntNet**	**AODV**	**DSR**
Normalized Routing Overhead	G	M	M	W
Average End-to-End Delay	G	M	M	W
Throughput	G	M	M	W

VII. CONCLUSION

In this paper, we proposed a new routing protocol for MANET based on Ant Colony Optimization principle, Blocking-ERS and Local Retransmission techniques. The proposed AntNet-RSLR algorithm improves the efficiency, robustness and reliability. The efficiency of proposed routing protocol AntNet-RSLR is shown to better than AntNet and the other two on demand routing protocols AODV and DSR. The proposed AntNet-RSLR routing protocol uses blocking-ERS and local retransmission along with principles of ant colony to reduce the EED, NRO and throughput. It enables optimal path routing and fast route discovery with better throughput and less delay.

REFERENCES

[1] A. Norouzi and B. Berk Ustundag, "Improvement of DSR protocol using group broadcasting", IJCSNS International Journal of Computer Science and Network Security, Vol.10(6), June 2010.

[2] A. Soltani, M. R. Akbarzadeh-T and M. Naghibzadeh, "Helping ants for adaptive network routing", Journal of the Franklin Institute, Elsevier, pp:389-403,2006

[3] C. Perkins, E. Belding-Royer, S. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing", Network Working Group, IETF RFC, RFC 3561, July 2003.

[4] D. Gan Chye Ong, "Ant Intelligence Routing Algorithm for Mobile Ad Hoc Networks", Master of Science in Information Technology, Malaysia University of Science and Technology, July, 2004.

[5] D. Lang, "On the Evaluation and Classification of Routing Protocols for Mobile Ad Hoc Networks ", PhD thesis, Fakultät für Informatik der Technischen, Universität München, Germany, 2006.

[6] F. Ducatelle, "Adaptive Routing in Ad Hoc Wireless Multi-hop Networks", PhD thesis, Faculty of Informatics, Università della Svizzera, italiana, May 2007.

[7] G. Di Caro and M. Dorigo, "Ant Colonies for Adaptive Routing in Packet-Switche Communications Networks", the Proceedings of the 5th Parallel Problem Solving from Nature, Amsterdam, 1998.

[8] G. Di Caro, "Ant Colony Optimization and its Application to Adaptive Routing in Telecommunication Networks", PhD thesis, Faculté Des Sciences Appliqué Es, Université Libre De Bruxelles, Bruxelles, 2004.

[9] G. Jayakumar and G. Gopinath, "Performance Comparison of Two On-demand Routing Protocols for Ad-hoc Networks based on Random Way Point Mobility Model", American Journal of Applied Sciences, Vol. 5(6), pp: 659-664, 2008.

[10] G. S. Sharvani, N. K. Cauvery and T. Rangaswamy, "Adaptive Routing Algorithm for MANET: TERMITE", International Journal of Next-Generation Networks, Vol.1 (1), Dec., 2009.

[11] I. Park, J. Kim, I. Pu, "Blocking Expanding Ring Search Algorithm for Efficient energy Consumption in Mobile Ad Hoc Networks", www.ubicc.org/journal_full_detail .aspx?id=18, Sep., 2008.

[12] I. Park and I. Pu, "Energy Efficient Expanding Ring Search", Proceedings The First Asia International Conference On Modeling & Simulation, pp: 198-199, 2007.

[13] J. du Plessis, "ACODV: Ant Colony Optimisation Distance Vector Routing Ad hoc Networks", PhD thesis, the Faculty of Engineering, Built-Environment and Information Technology, University of Pretoria, South Africa , Nov. 2005.

[14] J. Wei Wang, H. Chung Chen and Y. Ping Lin, "A Secure Destination-Sequenced Distance-Vector Routing Protocol for Ad Hoc Networks", Journal of Networks, Vol. 5(8), Aug. 2010.

[15] K. Fall and K. Varadhan, editors. "The ns Manual", The VINT Project, UC Berkeley, LBL, USC/ISI and XEROX PARC, 2001.

[16] L. Layuan, Y. Peiyan, and L. Chunlin, "Performance evaluation and simulations of routing protocols in Ad hoc networks," Computer Communications, vol. 30, pp: 1890-1998, 2007.

[17] M. Abdullah and H. Bakhsh, "Agent-based Dynamic Routing System for MANETs", ICGST-CNIR Journal, Vol. 9(1), July 2009.

[18] M. Dorigo, V. Maniezzo, and A. Colorni, "The ant system: Optimization by a colony of cooperating agents", IEEE Transactions on Systems, Man, and Cybernetics Part B: Cybernetics, Vol. 26(1), pp: 29-41, 1996.

[19] M. Gunes, U. Sorges and I. Buouazizi, "ARA-The Ant-Colony Based Routing Algorithm for MANETs", International Workshop on Ad Hoc Networking, Vancouver, Canada, 2002

[20] N. Jaisankar and R.Saravanan, "An Extended AODV Protocol for Multipath Routing in MANETs", International Journal of Engineering and Technology, Vol.2 (4), Aug., 2010.

[21] N. Mistry, D. C. Jinwala, and M. Zaveri, "Improving AODV Protocol against Black hole Attacks", International Multiconference of Engineers and Computer Scientists, hong kong, Vol. II, 2010.

[22] P. R. Jasmine Jeni, A. Vimala Juliet and B. Shaji, "MDSR (Modified Dynamic Source Routing) and AODV (Ad hoc On Demand Distance Vector) in MANET", European Journal of Scientific Research, Vol. 39 (4), pp: 606-612, 2010.

[23] P. Sateesh Kumar and S. Ramachandram, "Genetic Zone Routing Protocols", Journal of Theoretical and Applied Information Technology, www.jatit.org, 2008.

[24] R. Kumar, V. Joshi and V. Dhir, "Performance Comparison of Routing Protocols in Mobile Ad Hoc Networks", International Journal of Engineering Science and Technology", Vol. 2(8), pp: 3494-3502, 2010.

[25] S. Basagni, M. Conti, S. Giordano, and I. Stojmenovic, "Mobile Ad Hoc Networking", A JOHN WILEY & SONS, Publication, 2004.

[26] S. Prasad, Y. P. Singh, and C. S. Rai, "Swarm Based Intelligent Routing for MANETs", International Journal of Recent Trends in Engineering, Vol. 1(1), May 2009.

[27] S. S. Dhillon, P. Van Mieghem, "Performance Analysis of the AntNet Algorithm", International Journal of Computer Networks, Elsevier, pp: 2104-2125, 2007.

[28] S. S. Tyagi and R. K. Chauhan, "Performance Analysis of Proactive and Reactive Routing Protocols for Ad hoc Networks", International Journal of Computer Applications, pp: 0975–8887, Vol. 1(14), 2010.

[29] W. Jia, D. Lu, G. Wang, and L. Zhang, "Local Retransmission-Based Gossip Protocol in Mobile Ad Hoc Networks", IEEE Communications Society subject matter experts for publication in the WCNC, 2007.