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AN IMPROVED MAINTENANCE STRATEGY IN AD HOC ON-DEMAND ROUTING PROTOCOLS FOR MOBILE AD HOC NETWORKS
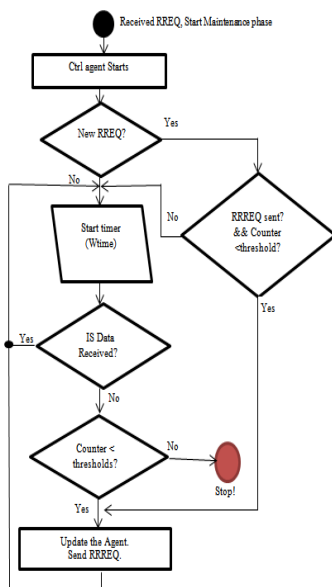
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Graphical abstract

Abstract

In high mobility and high traffic load network situations, the delay time is affected with high end-to-end delay in reactive routing protocols such as AODV. In this paper we proposed an enhanced receiver-based AODV (ERB-AODV) routing protocol by improving the maintenance phase in AODV. ERB-AODV protocol focuses on decreasing the end-to-end delay and the control overhead in high mobility and traffic load. The receiver node uses a controller agent to update the sender node of the current available path. The agent works depend on the history of receiving data packets. Using glomosim, the ERB-ADOV protocol outperforms the AODV protocol in high mobility and traffic load. Results show that, in high mobility, the delay is decreased by 81% and the control overhead is decreased by 77%. The delay is decreased by 91% in high traffic load, and decreases the control overhead by -77% compared with AODV protocol. These results show the improvement of network delay using the new maintenance strategy on on-demand routing protocols for MANETs.

Keywords: Mobile Ad hoc Network, reactive routing protocol, AODV, maintenance phase, glomosim

1.0 INTRODUCTION

Mobile ad-hoc networks (MANETs) consist of a set of devices with wireless facility (nodes) that are connected together through wireless links. This type of network is suitable in applications with limited resources and time. Examples of applications in MANETs are including military, rescue and emergency, conferences and meetings. MANET is easy to deploy in fast and simple ways as it requires only two or more mobile nodes [1]. In addition to MANET, there are different types of ad hoc networks, which are wireless sensor network (WSN) [2, 3], vehicular networks (VANET) [4], and underwater wireless networks [5]. With these networks and with the absence of a base station, each node acts as a router that manages the network. It learns about the network and communicates with other nodes by responding with different data/control packets. As nodes have limited resources (i.e. limited battery life, memory, and bandwidth), the communication life between them is limited and depends on the network environment (for example: static, dynamic, dense, congested, etc.).

In situations where network topology is frequently changes, the link between neighbor nodes becomes transient. This problem occurs in high mobility scenarios where nodes locations are not stable. In this regard, mobile nodes must update its route information to adapt to the new form of topology. That means that all the nodes need to resend its routing information. In addition to this problem, the

end-to-end delay will be certainly noticed because the sudden loss of route when losing the current path to the destination [6]. To deal with this issue, these problems have to be considered when designing a routing protocol. Routing protocols have to keep the overhead as low as possible, and find paths with less congestion. In addition, the protocols must be adaptive to frequent topology changes. In addition, the nodes have limited resources effect on the network performance especially the memory. For instance, when number of nodes increases, the traffic load becomes more in the middle of the topology and as a result the network becomes congested. Routing protocols needed to have an efficient mechanism to keep the source aware about new available paths.

Ad hoc on-demand distance vector (AODV) [7] routing protocol is a reactive routing protocol that starts when a sender node has data to send to another node, which is the receiver node. In this case, the sender will broadcast a request packet for the route, RREQ, to discover the path. The receiver node, upon receiving the request packet will send a unicast reply packet, RREP, which follows the reverse path through the upstream nodes toward the source node to start sending data packets. When a link has broken in the route, the intermediate node sends a route error packet, RRER, to inform the sender node of the problem. The sender node starts the discovery phase again if demanded to find new path to the receiver node. Limitation of AODV protocol is as follows: during the discovery phase, if the reply packet faced problems reaching the sender, the sender must start the discovery process all over again which increases the overhead in high mobility and high traffic load and affects the network performance especially in terms of increasing network delay. In addition, reliability to find new paths with less network flooding to discover a new path becomes one of the important challenges which has attracted researchers in improving distance vector routing protocols [8, 9]. Different protocols try to improve the AODV by focusing on the network QoS such as delay, bandwidth, or decreasing the control overhead. Examples of these protocols are in [10, 11], and a review for QoS protocols can be found in [12]. These protocols may not work efficiently when the network is less reliable with the limited resources of the network or with high mobility.

In receiver-based routing protocol RB-AODV [13], the authors have proposed a protocol based on broadcasting reverse request packets focused on the sender node. When the receiver node receives the first request packet, the reply packet will be sent as unicast to the sender node. After that, the receiver waits for a period of time to receive data packets. When this timer expires, the reverse request control packet is broadcasted to update the sender with the new path. The intermediate nodes treat this control packet like the request packet issued by the sender in AODV. When the sender node receives the first

control packet, it starts sending the data packets using this new path. The receiver node continues broadcasting the control packets until three successive expired times with no received data from the sender. This protocol decreases the delay and overhead when compared with AODV protocol. The protocol still suffer of increasing control overhead while there is no controlling when to stop broadcasting control packets in the network.

The authors in [14] have suggested to do bidirectional repair process, to improve the maintenance phase in ad hoc on-demand routing protocol, by allowing the intermediate nodes to send error packets to both end nodes, i.e. sender and receiver nodes. The receiver node along with sender node, broadcast a reverse RREQ packets. The control packets will not be farther broadcasted when intersected in an intermediate node. The intermediate node then send reply packet to update the nodes in the path toward the sender. However, even with the use of the receiver node in discovery or maintenance processes, the distance vector on-demand single paths routing protocols suffer from high end-to-end delay in high mobility conditions and traffic load [15]. A delay constraint AODV (DC-AODV routing protocol proposed by [16] to enhance the local repair algorithm of AODV protocol. When intermediate node starts repairing the broken link to the destination, it broadcasts RREQ packet to the receiver node with source ID of the sender node instead of intermediate ID. This is to make sure all upstream intermediate nodes along with the source node will get the updated information to avoid the redundant route repair operation. Another route recovery for AODV protocol proposed in [17]. This protocol selects backup nodes who hear the transmission of data packet along the active path. Each of these nodes maintains a local routing table which contains the possible backup routes in case of data packet transmission failure.

Therefore, in this paper, the Enhanced Receiver-Based Routing Protocol (ERB-AODV) protocol tries to decrease the delay and overhead in high mobility and traffic load. The idea is to face the congestion be sending broadcast from the receiver during the demand of the receiver to send data. These packets will travel through uncongested nodes and find available paths with less repairing time as in other on-demand protocols. The receiver role is to update the sender of the currently available path that can be used. As a result, the path acquisition time is decreased and the overhead is also decreased. This paper enhanced (RB-AODV) [13] protocol by decreasing the number of control packets issued by the receiver for updating the sender for the new path. This is by tracking the received data packets during a specified time.

The flow of this paper is outlined as follows: section 2 explains the ER-AODV routing protocol. Section presents the simulation results. Section 4 concludes the paper works.

2.0 ENHANCED RECEIVER-BASED AODV ROUTING PROTOCOL

Sending broadcast control packets from the receiver node to the sender node will decrease the control overhead in the network as proven in R-AODV protocol for minimizing the overhead during the discovery process. The proposed ERB-AODV is using this mechanism in maintenance phase to reduce the overhead especially in high mobility and high traffic load networks. In such condition, paths currently in use are vulnerable to breakage and the sender node will broadcast the network looking for new a path. Another advantage is that the broadcast packets , issued by receiver node, given the chance to decrease the time needed to discover new path, and hence the delay time is less compared to ordinary mechanisms such in AODV protocol. The source node uses the current active path when receiving first control packet. The proposed ERB-AODV protocol follows the same AODV routing protocol with two main phases, discovery phase and maintenance phase.

2.1 Discovery Phase

In this phase, when a sender node needs to communicate with the receiver node, it first looks in the routing table for any available path. If there is no valid path, the sender node will broadcast a control packet requesting for a path to the receiver node. This control packet, called route request packet (RREQ), contains information like the address of both sender and receiver nodes addresses and sequence numbers, the number of hops and the broadcast ID. Every intermediate node sends the first RREQ packet received with the same broadcast ID issued by the sender node looking for a receiver node. In addition, the intermediate node saves this information in the routing table to be used when building the path. When the receiver node received the first RREQ packet, it sends a unicast reply packet (RREP) back to the sender node. The sender node then starts sending data packets upon receiving the reply packet.

2.2 Maintenance Phase

In this phase, when the first session was created between the sender and receiver nodes through the discovery phase, the receiver node started controlling communication status. This is done by designing the receiver controller agent (Rec_Ctrl) as shown in Table 1. The receiver node starts a timer known as waiting time (Wtime) when sending the reply packet. The purpose of this timer is to check the number of times the receiver node receives data packets. If the receiver node did not receive any data packets during this time (dataReceivedFlag =0), then the receiver node broadcasts a receiver route request packet (RRREQ) looking for a path to

connect with the sender node as depicted in Figure 1. The isSent will be set to 1, and the agent will re-establish the Wtime again. isSent is used here to determine if the agent must be restarted even when receiving new request packets. A value of 1 means the agent is in the action of communicating with the sender node and will broadcast the RRREQ when Wtime expires. If zero, the receiver node has stopped broadcasting the RRREQ packets. The RRREQ acts like the RREQ in the discovery phase. Upon receiving the first RRREQ packet by the sender node, the sender starts using this new path to send data packets directly.

Table 1 Rec_Ctrl agent

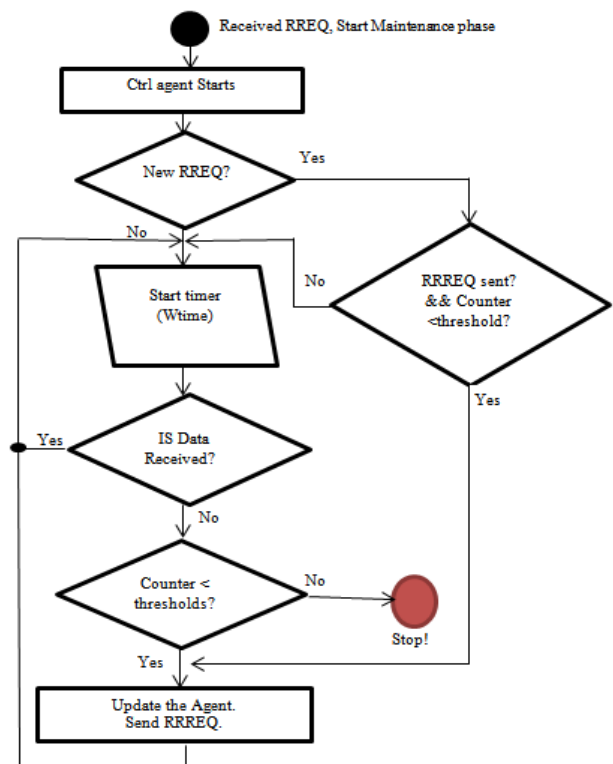| Rec-Ctrl variables	Role
dataReceivedFlag	Indicate if there is data received
Counter	Count the number of sent RRREQ
isSent	Indicate if already sent RRREQ
Wtime	Period of time waiting to receive data packets
Cthreshold	Maximum number of sent RRREQ without receiving data packets of each Wtime

Figure 1 The path maintenance process by receiver node

In Equation 1, the Wtime is calculated as follows:

$$Wtime = x \times nodetraversaltime \times numberofhops_i \qquad (1)$$

where x is used to define the number of times we need to wait to receive data packets.

If the receiver node has received any data packets during Wtime timer, then it will start the Wtime again without sending the RRREQ packet. The agent here assumes that the current connection still working with no problem. If after Wtime expires and there is no data received, the RRREQ packet will be broadcasted through the network. The controller will stop sending the update packets when the counter reaches Cthreshold. The agent learns there are no need for another connection and waits for new session to start.

The reason for not receiving data packets could be either the sender finished sending data packets, or there is a problem in the active path. It is assumed that the intermediate nodes stop sending error packets to the sender node in the case of error. Error packets increase the overhead in the network and also increase the delay time to find a path. The error notifications will be used when deal with multipath in future works.
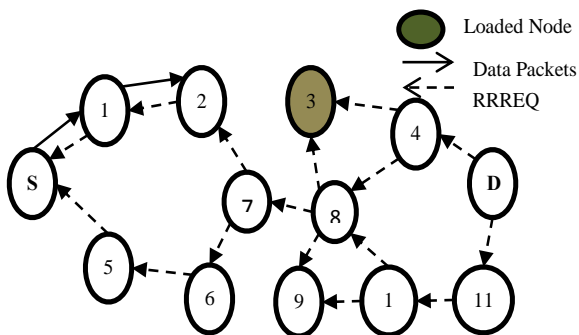

Figure 2 Exploring a new path after Wtime Expires by receiver node

3.0 RESULTS AND DISCUSSION

The simulation is used to test and verify the proposed protocol is GloMosim [18]. The simulation configuration is shown in Table 2. The experiment is to evaluate the performance of ERB-AODV and RB-AODV in different mobility conditions and to compare it with AODV protocol. The mobility model used here is the random way point (RWP) model which is a common mobility model used in the simulation of MANET. RWP supports random locations of nodes with random movement after each pause time and with varied speed. Node speed is varied between a minimum of 0m/s to maximum 10m/s which is equivalent to about 36 km/h in vehicular. The nodes move from one location to another with holding times ranging between 0 second (nonstop nodes) to 10 seconds which is called pause time. The traffic generator is the constant bit rate (CBR) with transfer rate 4, 8, and 12 packets per second (pkt/s), in order to test the protocols under high traffic load. The data packet size is 512 bytes.applicability of the present model.

Table 2 Simulation configuration parameters

Parameter Name	Parameter Name
Terrain size	1000X1000 m^2
No. of nodes	50
Mobility model	RWP
Max. Speed	10 m/sec
Pause time	0, 5, 10 sec
Traffic generator	CBR
Packet size	512 Bytes
Traffic speed	8 pkt/sec
X in Wtime	8

The routing protocols that are tested: AODV, RB-AODV, and the proposed protocol ERB-AODV. The performance metrics used are the delay, and control overhead. The improvement of proposed protocol compared to AODV protocol is measured using the formula:

$$Improvement = \frac{ERBAODV - other\ protocol}{other\ protocol} \times 100 \qquad (2)$$

The evaluation metrics are as follows:
- Packet delivery ratio: computed as the ratio of the number of packet received by receiver node to the number of packet sent by sender node.
- End-to-End delay: computed as the average delay since the sender node's application layer issues data packets until the receiver node process these packets successfully.
- Control overhead: computed as the average number of control packets flooded the network as broadcast or unicast control packets.

The first experiment is to evaluate the performance of ERB-AODV and RB-AODV in different mobility conditions and to compare it with AODV protocol. The mobility model used here is the RWP model. The pause time is varied between 0 sec (i.e. nodes do not stop) and 10 sec. The maximum speed used here is 10 m/sec (approximately 36 Km/H). The traffic load used here is 8 pkt/sec.

Figure 2 shows an example of the maintenance phase. Let's assume that during sending data, node 3 cannot receive more data packets. The receiver node D broadcasts RRREQ packets after Wtime expires where no data has been received. The sender node S will receive these control packets and decide to select the new path which is the first RRREQ packet received. Every intermediate node receives different RRREQ packets, but the active one to be used is the first one received with same RRREQ broadcast I.D. and new destination sequence number to prevent looping.

The average packet delivery ratio as shown in Figure 3 shows that ERB-AODV outperforms RB-AODV in pause time 0 sec. The latter broadcast more control packets and performance was affected by increased packet loss. Compared to AODV, the performance of ERB-AODV shows better results in terms of PDR. When the pause time increases, it is clear that the error caused by the congestion is worse than the error caused by mobility. In pause time 0 sec, the loss of path is not because of the traffic load, but because of the dynamic change of the topology. When the node slows down, the traffic load effects start showing by filling the intermediate nodes with data packets. As a result, the network becomes more congested, and the packet loss increases. The ratio here as defined as number of packets received to packets sent. In pause time 10 sec, the sender node sent more data than what was received compared to pause time 0 sec.
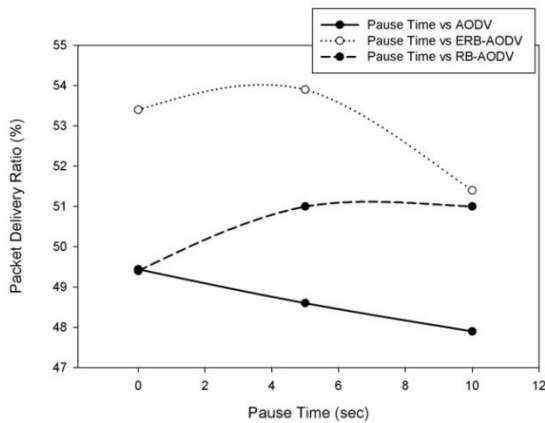

Figure 3 Packet delivery ratio with varied pausing time

Figure 4 shows the impact of the mobility in high traffic load on the end-to-end delay performance. The performance of both receiver-based mechanisms outperforms AODV protocol. The improvement obtained by ERB-AODV at pause time 0 sec is that the end-to-end delay is less by 81% compared to AODV protocol, and 78.8% less at pause time 10 sec. Although RB-AODV sends update packets periodically which affect the overall control overhead, it gives the sender new path to be used. For that, the delay is close between RB-AODV and the ERB-AODV protocols.
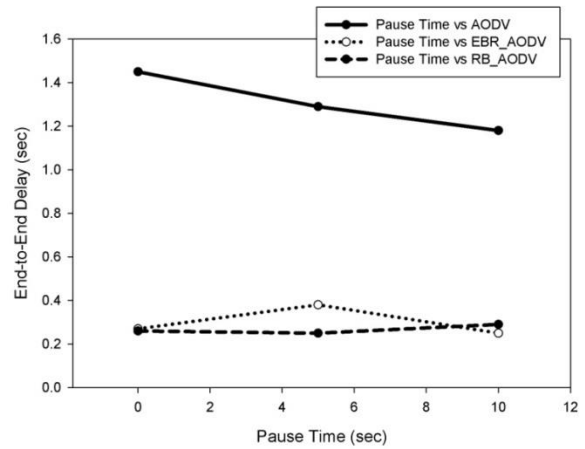

Figure 4 End-to-End delay with varied pausing time

The average control overhead as shown in Figure 5 verifies that RB-AODV broadcasts more control packets than ERB-AODV. The former broadcasts the update packets from the receiver node after each Wtime expires, whereas ERB-AODV only broadcasts control packets when there is no data packet received during the Wtime period. The improvement obtained by ERB-AODV protocol is that the control overhead is decreased by 77% at pause time 0 sec, and 80% at pause time 10 sec, when compared with AODV protocol.
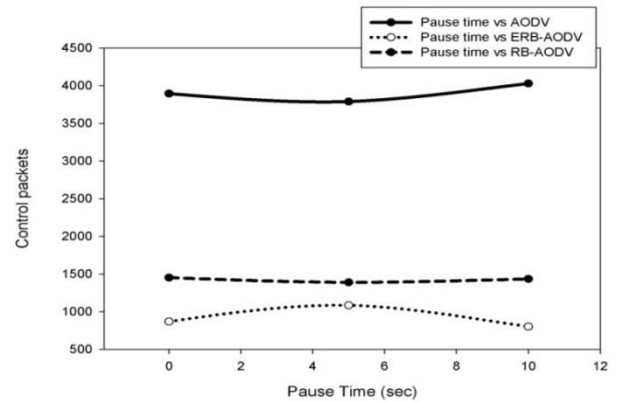

Figure 5 Control overhead with varied pausing time

Next test is to compare the ERB-AODV with the standard AODV routing protocol in different traffic load. We focus here to test the enhanced protocol with AODV only without comparing with RB-AODV protocol. In the previous experiment we showed the superiority of the ERB-AODV protocol to RB-AODV protocol in different mobility movements. The traffic load has been varied as 4 packets/sec, 8 packets/sec, and 12 packets/sec. The pause time was 5 seconds with max speed 10 m/sec.

As depicted in Figure 6, the packet delivery ration of AODV is better than ERB-AODV. This indicates that ERB-AODV outperforms AODV protocol upon increasing the traffic load. At load of 12 pkt/sec, the

ERB-AODV increases the performance of packet delivery ratio 29.8% compared to AODV protocol. The low delivery ration in low load of ERB-AODV protocol is because the control packets issued by the receiver node congested the network while not needed. The ratio in both protocols is decreased with high load because of the congestion caused by the data load and also the control packets. The packet lose in this case will increase. When an intermediate node is queuing data and no response has been received from next node to send clear to send packet, the intermediate node will drop the data packets. In case of AODV protocol, the intermediate node sends an error packet to sender node. Sender node broadcast request packets over the network. This is increased in high traffic load, and the loss of packets in AODV protocol increases. In ERB-AODV protocol, intermediate nodes do not send error packets. The receiver node updates the sender with new paths which currently can be used to transmit data. As a result, in high traffic load, the delivery ratio increases as compared to AODV protocol.
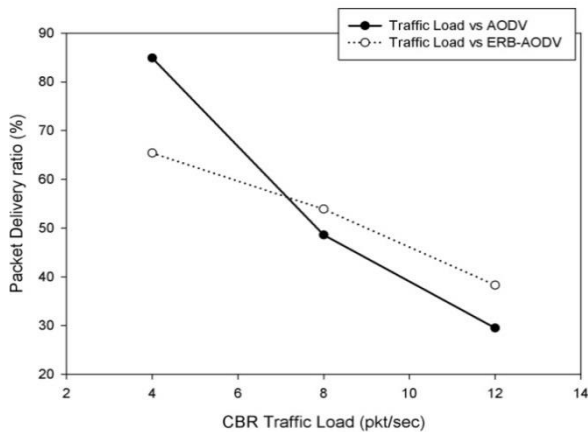

Figure 6 Packet delivery ratio in different traffic rate

The average end-to-end delay, shown in Figure 7, has been improved in ERB-AODV routing protocol when the load increases more than 4 pkt/sec. The improvement in performance shows that the ERB-AODV protocol decreases the delay by 70% and 91% as compared to AODV protocol with traffic load 8 pkt/sec and 12 pkt/sec respectively. The updates from receiver side of current path decreases the time to acquire a new route in heavy conditions. This mechanism prove that when the communication in network is in difficult condition like battle fields, earthquake, emergency or rescue scenarios, the ERB-AODV protocol is suitable to be used.
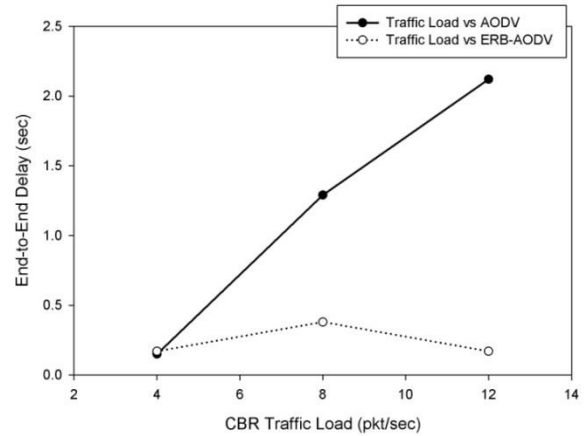

Figure 7 End-to-End delay in different traffic rate

The average control packets used in finding and updating paths are shown in Figure 8. The AODV protocol uses more control packets in high traffic load because of the need to explore and broadcast controls when errors occur as illustrated by the delivery ratio as shown above. The ERB-AODV protocol broadcasts the control packets based on traffic load, because the receiver node broadcasts the updating control packets when there is no data received in fixed Wtime. The improvement here is that ERB-AODV protocol decreases the overhead by 71% and 77% in traffic load 8 and 12 pkt/sec respectively, compared to AODV protocol.
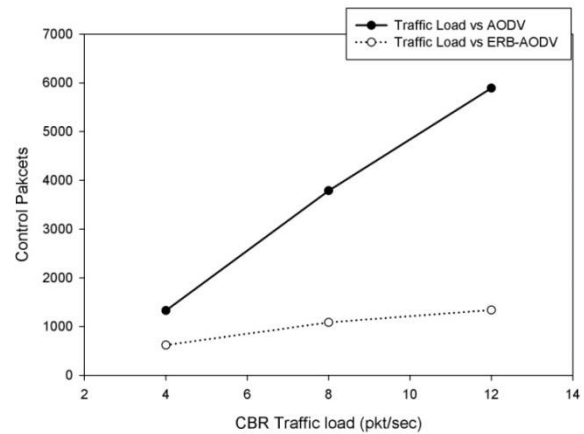

Figure 8 Control overhead in different traffic rate

4.0 CONCLUSION

In this paper, we have illustrated the effects of high mobility and traffic load on network performance in ad hoc on-demand routing protocol as in AODV. AODV suffers in such aggressive situations where when traffic load increases, end-to-end delay increases along with an increasing in packets drop. There is a need to address how to keep up the

connection between end nodes, by studying the maintenance phase in reactive routing protocols. For that, ERB-AODV protocol proposed enhanced maintenance phase in AODV protocol. Receiver node try to update the source node with new path when predicts problem in current path. The results show that ERB-AODV protocol improved the network performance when compared with the standard AODV protocol. The results show that, the end-to-end delay is decreased by 81% compared to AODV in high mobility. And control overhead is decreased by 77%. Updating the source with new available path before the current used path is broken is important in decreasing the delay and control overhead. The delay is decreased by 91% in high traffic load, and decreases the control overhead by -77% compared with AODV protocol. For future work, we will focus on enhancing the PDR and study the improvement on performance by selecting multiple paths from update packets.

Acknowledgement

References

[1] Murthy, C. S. R. and B. Manoj. 2004. *Ad Hoc Wireless Networks: Architectures And Protocols.* Pearson Education.
[2] Guo, W. and W. Zhang. 2014. A Survey On Intelligent Routing Protocols In Wireless Sensor Networks. *Journal of Network and Computer Applications.* 38(1): 185-201.
[3] Sara, G. S. and D. Sridharan. 2014. Routing In Mobile Wireless Sensor Network: A Survey. *Telecommunication Systems.* 57(1): 51-79.
[4] Sharef, B. T., R. A. Alsaqour, and M. Ismail. 2014. Vehicular Communication Ad Hoc Routing Protocols: A Survey. *Journal of Network and Computer Applications.* 40(1): 363-396.
[5] Kheirabadi, M. T. and M. M. Mohamad. 2013. Greedy Routing In Underwater Acoustic Sensor Networks: A Survey. *International Journal of Distributed Sensor Networks.*
[6] Al-Qassas, R. S., L. M. Mackenzie, and M. Ould-Khaoua. 2006. Performance Study Of End-To-End Traffic-Aware Routing. *Simulation Symposium, 2006. 39th Annual.* IEEE.
[7] Das, S. R., E. M. Belding-Royer, and C. E. Perkins. 2003. Ad Hoc On-Demand Distance Vector (AODV) Routing.
[8] Kim, C., E. Talipov, and B. Ahn. 2006. A Reverse AODV Routing Protocol In Ad Hoc Mobile Networks. *Emerging Directions in Embedded and Ubiquitous Computing.* 4097: 522-531.
[9] Mohammed, M. N. and N. Sulaiman. 2014. Performance Analysis of DSR, AODV On-Demand Routing Protocols. Mobile Ad Hoc Networks. *Advanced Science Letters.* 2014. 20(2): 359-363.
[10] Hu, C.-C. 2011. Delay-Sensitive Routing In Multi-rate MANETs. *Journal of Parallel and Distributed Computing.* 71(1): 53-61.
[11] Zhu, C. and M. S. Corson. 2002. QoS Routing For Mobile Ad Hoc Networks. *INFOCOM 2002. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies.* Proceedings. IEEE.
[12] Asokan, R. 2010. A Review Of Quality Of Service (Qos) Routing Protocols For Mobile Ad Hoc Networks. *International Conference on Wireless Communication and Sensor Computing, 2010. ICWCSC 2010.* IEEE.
[13] Al-Nahari, A., M. M. Mohamad, and S. Al-Sharaeh. Receiver-based AODV Routing Protocol for MANETs. *13th International Conference on Intelligent Systems Design and Applications (ISDA), 2013.*
[14] Huang, S. C. and H. Y. Chang. 2014. A Bidirectional Route Repair Method for Wireless Mobile Ad Hoc Networks. *The Computer Journal.* 58: 338--353.
[15] Marina, M. K. and S. R. Das. 2006. Ad Hoc On-Demand Multipath Distance Vector Routing. *Wireless Communications and Mobile Computing.* 6(7): 969-988.
[16] Shijie, L., L. Xu, and F. Qijing. 2012. An Improved AODV Local Repair Algorithm Based On Delay Constraint. *11th International Conference on Signal Processing (ICSP), 2012.* IEEE.
[17] Junghwi, J., L. Kiseok, and K. Cheeha. Fast route recovery scheme for Mobile Ad Hoc Networks. *International Conference on Information Networking (ICOIN), 2011.*
[18] Zeng, X., R. Bagrodia, and M. Gerla. 1998. GloMoSim: A Library For Parallel Simulation Of Large-Scale Wireless Networks. *Twelfth Workshop on Parallel and Distributed Simulation, 1998. PADS 98.* Proceedings. IEEE.