PERFORMANCE STUDY OF AODV ROUTING PROTOCOL IN MOBILE AD-HOC SENSOR NETWORKS

[1]MOHAMAD NAZIM JAMBLI, [2]HALIKUL LENANDO, [3]JOHARI ABDULLAH, [4]SINARWATI MOHAMAD SUHAILI

[1,2,3]Faculty of Computer Science & Information Technology, Universiti Malaysia Sarawak, 94300 Sarawak, Malaysia
[4]Centre for Pre-University Studies, Universiti Malaysia Sarawak, 94300 Sarawak, Malaysia
E-mail: jmnazim@fit.unimas.my, cool@fit.unimas.my, ajohari@fit.unimas.my, mssinarwati@preuni.unimas.my

Abstract- The design of any routing protocols for Mobile Ad-hoc Sensor Networks (MASNETs) is a complex issue because of the diversity of their potential applications that are constrained by power sources and dynamic mobile networks. These characteristics impose a new demand on the routing protocol which is a consequence of the mobile nodes. A mobile node can change position quite frequently, which means that we need a routing protocol that quickly adapts to topology changes. Using AODV routing protocol in MASNETs' application shows degradation in network performance due to high density and speed of mobile nodes. In this paper, through extensive simulation we evaluated the capability of Ad-hoc On-Demand Distance Vector (AODV) routing protocol on how far it can react to network topology change in MASNETs. We present the analysis of the impact of mobile nodes on the average percentage of packet loss with different speed, density and route update interval (RUI) of mobile nodes. Our performance study demonstrates that by applying the existing AODV in MASNETs, the results show a high average percentage of packet loss due to serious broken link caused by nodes movement. We also identify some key research problems that need to be addressed for successful implementation of AODV in MASNETs.

Keywords: Mobile Ad-hoc and Sensor Networks, Ad-hoc On-Demand Distance Vector, Performance Study, Simulation.

I. INTRODUCTION

The rapid development of wireless communication technologies and portable mobile devices such as laptops, PDAs, smartphones and wireless sensors brings the best out of mobile computing particularly mobile ad-hoc and sensor networks. Mobile computing can be defined as the use of portable mobile devices in conjunction with mobile communications technologies that allows transmission of data, via mobile devices, without having to be connected to a fixed physical link as in Mobile Ad-hoc Networks (MANETs) and Wireless Sensor Networks (WSNs). The design of routing protocols for both types of networks, which can be called as Mobile Ad-hoc Sensor Networks (MASNETs), is a complex issue because of the diversity of their potential applications, ranging from small, static networks that are constrained by power sources, to large scale highly dynamic mobile networks.

MASNETs also have certain characteristic, which imposes new demands on the routing protocol. The most important characteristic is the dynamic topology, which is a consequence of the mobile nodes. A mobile node can change position quite frequently, which means that we need a routing protocol that quickly adapts to topology changes. In designing such routing protocol we have to consider the constraints of the nodes in MASNETs that are often very limited in resources such as processing capacity, storage, battery power and bandwidth. Since the nodes are forwarding packets for each other towards sink, some sort of efficient routing protocol is necessary to make better routing decisions with less energy consumption in mobile environment. Before designing a better routing protocol for MASNETs, there is a need to identify the effects of node mobility on a routing protocol for such mobile networks. In this paper, through extensive simulation we evaluated the capability of a well-known Ad-hoc On-Demand Distance Vector (AODV) routing protocol on how far it can react to network topology change in MASNETs. We present the analysis of the impact of mobile nodes on the average percentage of packet loss with different speed, density and route update interval (RUI) of mobile nodes. The simulations are performed using Avrora network simulator, which is the most appropriate simulation tool for evaluating MASNETs as in. The rest of the paper is organized as follows: Section II includes the recent related work on the performance evaluation of AODV. The AODV routing protocol description is summarized in section III. The simulation environment and performance metrics are described in Section IV. We present the experimental results in section V. Section VI concludes the paper and outlines the future work.

II. RELATED WORK

This section reviews the recent related work which directly or indirectly aims at evaluating performance of the existing AODV routing protocol. Most of the previous work on performance evaluation of AODV focus on MANETs as in. However, not many papers in literature evaluate the performance of AODV in WSNs especially in mobile environment. Some work on performance evaluation of AODV in WSNs assumed sensor nodes either static or only sink nodes

are mobile. For instances, the authors of studied the performance of AODV family of protocols in static environment. They assumed that the WSN is static, where all the sensor nodes have the same radio range and energy is uniformly distributed among all sensor nodes. In this paper, various performance metrics like packet delivery ratio, average network delay, network throughput and normalized routing load have been investigated. However, they are not taken into account energy consumption as one of the metrics in evaluating the performance of AODV in WSN.

The authors of have evaluated the performance of AODV over IEEE 802.15.4 in WSN with mobile sinks through extensive ns-2 simulations. In their simulation, they investigated the fundamental problems of AODV and analyzed the influence of incorporating multiple mobile sinks. However, they only assumed the sinks are mobile but other sensor nodes are static. Although they have studied the performance of energy, packet loss ratio and delay with different sink velocity, they did not investigate the performance of protocols under high mobility and larger density of mobile nodes in the network, which may lead to network congestion. This paper concentrates on evaluating the performance of AODV in MASNETs environment, where we set sensor nodes are all mobile with static sink as setup in habitat monitoring application. We investigate the impact of changing mobile node speed, density and RUI on the average percentage of packet loss.

III. AODV ROUTING PROTOCOL DESCRIPTION

AODV stands for ad hoc on-demand distance vector protocol because route discovery in AODV is "on-demand". This protocol initiates a route discovery process only when it has data packets to send and it does not know any route to the destination node. It is a routing protocol designed for ad hoc networks and is one of the most popular reactive routing protocols in MANET. Being a reactive routing protocol AODV uses traditional routing tables, one entry per destination and destination sequence number (DSN) to determine the freshness of routing information and to prevent routing loops. This will greatly increase the efficiency of routing processes. AODV consists of two basic routing operations such as route discovery and maintenance. There are also various types of control messages used in the routing process of AODV as explained further below.

A. Control Messages

Route Request (RREQ) message, Route Reply (RREP) message, Route Error (RERR) message and HELLO messages are the control messages used for the discovery and breakage of route. The RREQ message is broadcasted by a node requiring a route to another node, RREP message is unicasted back to the source of RREQ message, RERR message is sent to notify other nodes of the loss of the link. HELLO messages are used for detecting and monitoring links to neighbours.

B. Route Discovery

Route discovery is initiated when a source node wants to find a route to a new destination or when the lifetime of an existing route to a destination has expired. During a route discovery process, the source node broadcasts a RREQ

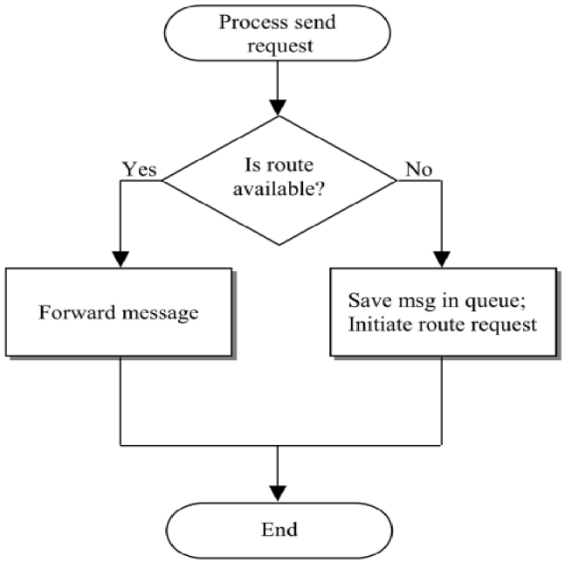


Fig. 1. Flow chart of a source node broadcasting a RREQ message

message to its neighbors. If any of the neighbors has a route to the destination, it replies to the query with a RREP messsage; otherwise, the neighbors rebroadcast the RREQ message until the sought route as shown in the flowchart (Figure 1). This is possible because each node receiving the RREQ message caches the route back to the originator of RREQ message. A route is said to be fresh enough when the DSN of the sought route in the recipient nodes routing table is greater than the DSN in the RREQ packet itself. A flag is set in the RREQ for establishing a reverse route between destination node and source node.

C. Route Maintenance

To handle the case in which a route does not exist or the query or reply packets are lost, the source node rebroadcasts the query packet if no reply is received by the source after a time-out. A path maintenance process is used by AODV to monitor the operation of a route being used. If a source node receives the notification of a broken link, it can re-initiate the route discovery processes to find a new route to the destination. If a destination or an intermediate node detects a broken link, it can choose to repair the link locally or send an RERR packet to notify its upstream nodes. An RERR message contains the list of those

destinations which are not reachable due the loss of connectivity. Whenever an end point receives RERR message it removes all the routes information of bad end point from it routing table. AODV only keeps the records of next hop instead of the whole route.

IV. SIMULATION ENVIRONMENT

Here we give the emphasis for the evaluation of performance of AODV routing protocol in MASNETs with various speed, density and RUI of mobile nodes. The simulations are performed using AVrora network simulator latest version Beta 1.7.115 that is an open source discrete event simulation tool,

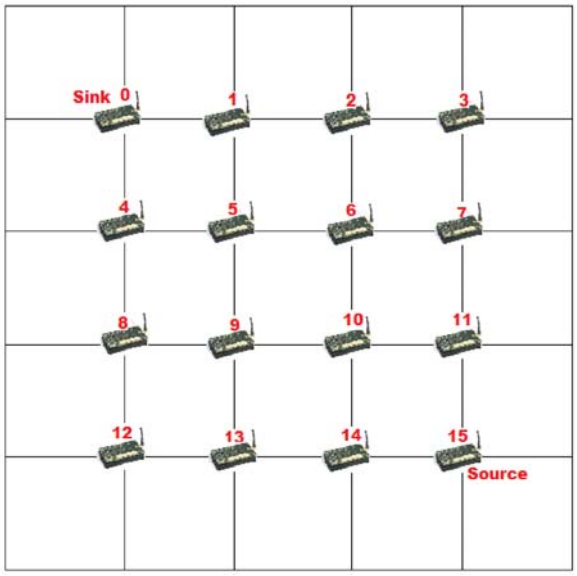


Fig. 2. Initial topology setup for the experiment settings of AODV Simulation

which means it simulates events such as sending, receiving, forwarding and dropping packets.

A. Network Simulator

AVRora is a suite of simulation tools for WSN by UCLA Compilers Group. It is originally created to simulate Atmel AVR microcontroller-based sensor nodes with clock- cycle accurate execution of microcontroller programs, allowing real programs to be run with precise timing. It takes an object dump of in tinyos programs over AVR platforms such as mica2/micaz and is capable of single node emulation for verification of the program as well as multiplenode simulation. AVRora is implemented in Java and runs code in an instruction-by-instruction fashion. However, the simulator attempts to achieve better scalability and speed than TOSSIM by avoiding synchronization of all nodes after every instruction. AVRora also provides many useful features to support the research on WSN, like control flow graph generation, energy analysis, and mobility extension model. The AVRora's extension model of Random Waypoint (RWP) mobility model is used to simulate different mobility settings in our experiments because this model is the most commonly used mobility model in this research area. In this mobility model, a node randomly chooses a destination and moves towards it. After reaching the destination, the node stops for a time defined by the 'pause time' parameter. After this duration, it again chooses a random destination and repeats the whole process until the simulation ends.

B. Simulation Setup

We consider a network of nodes placing initially in a grid topology as shown in Fig. 2. The performance of AODV is evaluated by keeping the mobility area and pause time of RWP mobility model constant and varying the velocity, density and RUI of mobile nodes for different experiment settings. TABLE I shows the simulation parameters used in this evaluation. In order to evaluate the capability of AODV routing protocol on how it reacts to network topology changes in MASNETs,

TABLE I
PARAMETERS VALUES FOR AODV SIMULATION

Parameters	Value
Simulator	AVRora-Beta 1.7.115
Protocol	AODV
Simulation duration	1000 seconds
Simulation area	75 m x 75 m
Number of nodes	16 nodes
Number of mobile nodes	8 nodes
Mobility model	Random Waypoint
Pause time	5 sec
Maximum Speed	10 m/s
Packet Rate	1 packets/sec

we focused on the average percentage of packet loss. This metric can be define as the average of packets sent by the source and the packet dropped (loss) before receiving by the base station (sink). It is determined by calculating the ratio of packets unsuccessfully delivered to the sink, to the total number of packets sent by mobile nodes.

V. EXPERIMENTAL RESULTS

There are several experiments have been conducted in order to show the impact of mobile nodes on AODV performance. Three important parameters have been analyzed which are various speed, density, and RUI of mobile nodes on the average percentage of packet loss as follows:

Effect of mobile node speed: The objective of this experiment is to observe the average percentage of packet loss when mobile nodes are moving at different speed. To study the effect of different mobile node's speed on the AODV performance, the mobile nodes are set to move consistently according to RWP mobility model in each experiment. By

increasing the speed of mobile nodes in the simulation, the mobility will also increase. Therefore, different levels of speed which increase gradually from 2 m/s to 10 m/s in step of 2 are configured.

Effect of mobile node density: The second experiment shows the effect of change in mobile node density (number of mobile nodes in the network) on the average percentage of packet loss as in the first experiment. In this experiment different number of nodes are mobile, which start from all nodes are static and increasing until 8 nodes are mobile (from 2 to 10 in step of 2) except for static sink. All nodes are moving consistently with speed of 2 m/s within 75m x 75m simulation area according to RWP mobility model.

Effect of mobile node route update interval: The objective of the third experiment is to study the effect of change in route update interval (RUI) on the average percentage of packet loss and total energy consumed.

In this experiment different RUI is used, where routing table is set up to be updated within 10 seconds up to 60 seconds.

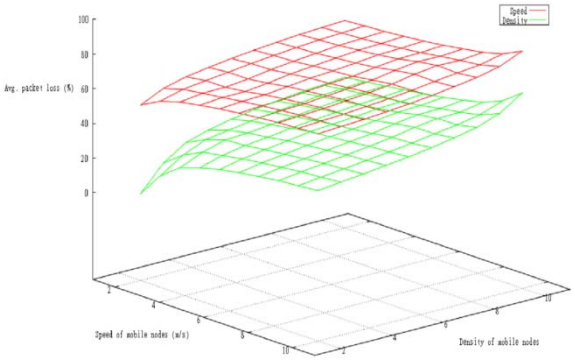


Fig. 3. The 3D graph between speed and density of mobile nodes

Speed	Avg. P. L. (%)	Density	Avg. P.L. (%)
2	51.13	2	0.03
4	61.40	4	33.42
6	69.22	6	39.54
8	78.87	8	48.01
10	86.84	10	62.64

TABLE II
THE AVERAGE PACKET LOSS (P.L.) FOR SPEED AND DENSITY OF MOBILE NODES

From the simulation results, we found that there is a direct relationship between these two properties of mobility. This is shown in Fig. 3 and Table II where the average percentage of packet loss for both speed and density of mobile nodes increased gradually from 2 to 10 m/s and from 2 to 10 mobile nodes respectively. This indicates that if more number of mobile nodes with high speed mobility in the network, the average percentage of packet will be higher. This is may due to the fact that the combination of mobility properties might double up the impact of mobility on AODV in mobile environment although the impact of speed is more than density of mobile nodes as in this 3D graph.

Furthermore, based on the experimental results of the effects of speed of mobile nodes and RUI on the average percentage of packet loss, we found that there is also a direct relationship between these two results. This is shown in Figure 4.8 and Table 4.13 where the average percentage of packet loss for both speed of mobile nodes and RUI increased gradually from 2 to 10 m/s and from 10 to 50 seconds respectively although the impact of speed is also more than RUI in this 3D graph. This indicates that if the node is moving in higher speed with longer RUI in the network, the occurrence of broken links is much more higher than the mobile nodes with high speed and density but with more frequent route update. It can clearly be seen from these experimental results that AODV is not performed very well when there is a high topology change in MASNETs due to increase in the speed and density of mobile nodes. The reasons are that AODV does not successfully find a new route for those packets and because

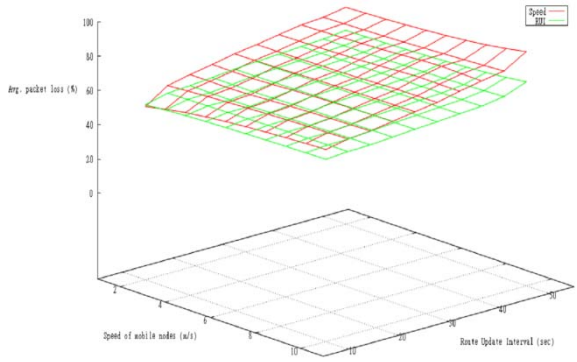


Fig. 4. The 3D graph between speed of mobile nodes and RUI

Speed	Avg. P.L. (%)	RUI	Avg. P.L. (%)
2	51.13	10	52.19
4	61.40	20	55.05
6	69.22	30	59.71
8	78.87	40	61.81
10	86.84	50	69.14

TABLE III
THE AVERAGE PACKET LOSS FOR SPEED OF MOBILE NODES AND RUI

broken links are not detected fast enough, resulting in that the mobile nodes keep sending packets on a broken link believing that it is still working properly.

VI. CONCLUSION AND FUTURE WORK

In this paper we have presented performance evaluation of AODV under various MASNEts scenarios on the average percentage of packet loss. We demonstrated that through extensive simulation that the AODV performance in mobile environment is not only affected by the speed and density of

mobile nodes but also the length of RUI and are therefore not suitable for MASNETs. From the simulation results, we can conclude that AODV cannot perform in MASNETs as good as in static WSNs because the routing protocol not be able to detect broken routes and react to topology change fast enough in mobile environment. In this case, we believe that there certainly is a need for an improvement in AODV for MASNETs for successful implementation of AODV in a mobile environment.

There are several avenues for further studies as follows:

To design a new routing protocol that able to react efficiently on network topology changes. Some sort of information such as RSSI (Received Signal Strength In-dicator) or LQI (link Quality Indicator) might be needed as the input to the routing protocol in order to improve the performance of AODV in mobile environment.

To integrate cross-layer design for energy-efficient working of AODV. For instance, we plan to let the mobile sink piggybacks its position information in AODV RREP packets, in order for the devices choose more energy efficient path.

REFERENCES

[1] "Mobile computing." http://en.wikipedia.org/wiki/Mobile computing. Accessed: 2012-09-30.

[2] P. Santi, "Topology control in wireless ad hoc and sensor networks," ACM Comput. Surv., vol. 37, pp. 164–194, June 2005.

[3] C. Zhu, L. Shu, T. Hara, L. Wang, and S. Nishio, "Research issues on mobile sensor networks," Communications and Networking in China CHINACOM 2010 5th International ICST Conference, pp. 1–6, 2010.

[4] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," Computer Networks, vol. 38, no. 4, pp. 393–422, 2002.

[5] E. M. Belding-Royer and C. E. Perkins, "Evolution and future directions of the ad hoc on-demand distance-vector routing protocol," Ad Hoc Networks, vol. 1, no. 1, pp. 125–150, 2003.

[6] M. Jambli, H. Lenando, K. Zen, S. Suhaili, and A. Tully, "Simulation tools for mobile ad-hoc sensor networks: A state-of-the-art survey," in Advanced Computer Science Applications and Technologies (ACSAT), 2012 International Conference on, pp. 1–6, Nov 2012.

[7] M. S. El-azhari, O. A. Al-amoudi, M. Woodward, and I. Awan, "Performance analysis in aodv based protocols for manets," in Proceedings of the 2009 International Conference on Advanced Information Networking and Applications Workshops, WAINA '09, (Washington, DC, USA), pp. 187–192, IEEE Computer Society, 2009.

[8] M. M. Morshed, M. H. Rahman, M. R. R. Mazumder, and K. A. M. Lutfullah, "Simulation and analysis of ad-hoc on-demand distance vector routing protocol," in Proceedings of the 2nd International Conference on Interaction Sciences: Information Technology, Culture and Human, ICIS '09, (New York, NY, USA), pp. 610–614, ACM, 2009.

[9] D.-W. Kum, J.-S. Park, Y.-Z. Cho, and B.-Y. Cheon, "Performance evaluation of aodv and dymo routing protocols in manet," in Proceedings of the 7th IEEE conference on Consumer communications and networking conference, CCNC'10, (Piscataway, NJ, USA), pp. 1046–1047, IEEE Press, 2010.

[10] Performance analysis of AODV, AODVUU, AOMDV and RAODV over IEEE 802.15.4 in wireless sensor networks, September 2009.

[11] C. Chen and J. Ma, "Simulation study of aodv performance over ieee 802.15.4 mac in wsn with mobile sinks," in AINA Workshops (2), pp. 159–164, 2007.

[12] C. Perkins, E. Belding-Royer, and S. Das, "Ad hoc on-demand distance vector (aodv) routing," 2003.

[13] B. Titzer, D. K. Lee, and J. Palsberg, "Avrora: scalable sensor network simulation with precise timing," in IPSN, pp. 477–482, 2005.

[14] P. Levis, N. Lee, M. Welsh, and D. Culler, "Tossim: Accurate and scalable simulation of entire tinyos applications," 2003.

★★★