Performance Enhancement of AODV Routing Protocol in Mobile Ad hoc Networks

Zouhair El-Bazzal, Khaldoun El-Ahmadieh, Ali Chamas Al Ghouwayel
School of Engineering - Department of Computer and Communications Engineering
Lebanese International University (LIU)
P.O. Box: 146404 Mazraa, Beirut, Lebanon
{zouhair.bazzal, ali.ghouwayel}@liu.edu.lb, khaldoun_ahmadieh@hotmail.com

ABSTRACT: *Ad-hoc On Demand Distance Vector (AODV) routing protocol has been one of the prominent routing protocols for Mobile Ad hoc Networks. AODV uses the hop count as a path selection metric. However, routing based on the hop count may not lead to optimal route selection. In this paper we propose a cross layered based routing protocol called Turbo-AODV (TAODV) where we modify AODV to calculate the weight of a certain route based on three factors, and then choose the route with the best weight. The three factors that make the base of route selection are: the received signal strength, the remaining energy and the remaining queue length. The route selection based on the following criteria ensures choosing the most stable route which has the less congested links. Performance evaluation through simulations showed that the proposed protocol performs better than AODV protocol in terms of packet delivery, normalized routing load, discarded packets on queues, and routing overhead.*

Keywords: MANET, AODV, QoS, Cross Layer

Received: 17 February 2012, Revised 13 April 2012, Accepted 17 April 2012

1. Introduction

Mobile Ad hoc Networks (MANETS) are characterized by a collection of wireless nodes which communicate with each other using high-frequency radio waves. These nodes arbitrarily and randomly change their locations and capabilities without the aid of any fixed infrastructure. Nodes in this network are able to move freely not bounded to the range of the access point. Thus nodes organize themselves to form a network when they come into the range of each other. MANETS have some problematic factors that must be considered. Some of these factors are energy limitations, variations in nodes capabilities, continuous change in routing table entries, etc. Moreover, MANETs have inherited the normal wireless networks problems like attenuation, fading and signal distortion.

The main problem is the routing in MANETS. There are still continuous studies to enhance the performance of existing routing protocols or to propose better routing protocols algorithms. These studies considered many directions like reducing the flooding of packets, finding stable routes, enhancing QoS, enhancing security and enhancing packet delivery ratio. Hence, any enhancement shall take into consideration the previous problematic factors. Routing is the process of determining the network path between two nodes upon the request of the data transmission from any of these two nodes. In routing process, there is at least one intermediate node before reaching the destination. Hence the routing protocol has two main functions, the selection of packets routes to many destinations and the delivery of these packets to their destinations. Each routing protocol is based on a certain routing algorithm to determine the optimal path to a certain destination using a certain metric. The metric used includes the number of hops to reach a certain destination, the available bandwidth and the load on the path. The routing protocol algorithm fills and maintains routing table which are responsible for caching route information to certain destinations. Mainly each routing table entry contains the next hop and destination. However, it may contain the destination address and multiple next hops to destination based on the routing algorithm used.

Routing is mainly divided into two categories static and dynamic routing. In static routing the routing tables are written and maintained by the network administrator. However, in dynamic routing the routing table entries depend on the state of the network and on the state of the destination (alive or unavailable). Hence, in dynamic routing each router notifies the neighbor routers that are present by flooding information packets in the network. The flooding of information packets in the network allows every router within the network to detect neighbor routers.

Route selection can be considered one of the most critical design constraints of any routing protocols. Selecting non optimal routes may increase delays, routing loads, decrease throughput and increase loss rate since the selected route will break quickly or nodes get congested. Most of the traditional ad hoc routing protocols use hop count as a metric for selecting paths from source to the destination. However, the shortest path may not always be the optimal way for selecting paths. Since shortest paths may contain congested nodes or nodes having weak connectivity degree among each other. Many issues must be taken into consideration while designing a MANET routing protocol. It is very challenging to enable communication when resources are distributed in an unreliable environment. Hence the routing protocol must take into consideration the best utilization for available bandwidth, battery life (which highly depends on the processing effort). Because of the dynamic topology, the path between two nodes will break at certain time. When the path breaks the routing protocol must find another efficient path to the destination while taking into account the best utilization of resources. Inefficient route discovery methods may increase the network load. In MANET, available bandwidth must be used in an optimal way. However, in order to have an efficient routing protocol, complete topology information is required. In MANET a routing protocol that maintains complete topology information cannot be used because it will increase node control messages that increases overhead and wastes bandwidth. Processing power and battery life are two factors that depend on each other. As more processing power is needed the battery consumption increases. Hence the design of a routing protocol must be efficient in a way to consume less processing power.

MANET routing protocols must operate in a distributed manner since nodes are mobile. Nodes can enter or leave a network without any type of restrictions makes depending on a centralized node inefficient. Moreover, the routing protocol must guarantee loop free routes and efficient routes maintenance method. Another property is that packet collisions must be minimized as much as possible by a certain routing protocol. Packet collisions can be minimized by making a more reliable broadcast strategy while discovering/rediscovering routes.

Recent studies in routing involve cross layer designs for multi-hop networks because of their effectiveness in selecting the most optimized routes. They aim to reduce the flooding of packets, find stable routes, and enhance QoS, security and packet delivery ratio. In this paper, we propose Turbo AODV (TAODV) a cross layer design version of the well-known AODV routing protocol. The modification considers route selection engineering process. In the classical AODV, the shortest path is chosen. However, it might be not the optimal path, since it doesn't take into consideration the nodes conditions or the connectivity degree between the nodes. The proposed cross layer design relies on information (remaining energy, RSS and remaining queue length) that can be obtained from lower layers. Mainly, routing packets headers are changed by adding new fields, routing packets forwarding algorithms are modified and the route selection algorithm at the destination is completely enhanced.

The paper is organized as follows. Section II presents a literature review. Section III describes the proposed cross layer design. Section IX presents the performance study based on simulations. Finally, Section V concludes this paper.

2. Literature Review

Classical internet routing protocols cannot be used because they don't take into consideration MANETs characteristics like battery life, processing consumption, links' conditions, and bandwidth availability. Proactive routing protocols consume lot of resources and increase the load on the network. Thus the attention was shifted to use reactive and hybrid routing protocols that conserve resources in a better way. However, reactive routing protocols are more interesting since hybrid routing protocols are proven to be not highly effective if a global positioning system (GPS) is not used to divide the network into zones. According to [1], OLSR (Optimized Link State Routing) allows high throughput but needs longer delay while establishing the routes when compared to AODV and TORA (Temporally Ordered Routing Algorithm). The study in [2] proposed a routing protocol called DYMO which allows high delivery fraction due to the fact of caching multiple routes to a destination; however, the jitter is long due to using stale routes. In [3], the authors showed that, when using AODV, the routing load increases as the number of nodes becomes high in the network. In [4], the authors proved that the performance of the routing protocols depends very much on the type of traffic (UDP, TCP). They showed that DSR (Dynamic Source Routing) has less routing load than AODV when the traffic type is UDP, but the opposite is true when TCP traffic is used.

Recently, cross layer designs have been extensively investigated due to their effectiveness in selecting optimal routes. A large number of cross layer designs have been proposed for mobile ad hoc networks. In [5], the authors present a cross layer integration approach for a power efficient routing protocol. The integration between power control in link layer and routing protocol at network layer intends to maximize the network lifetime taking into consideration the limited power of the nodes. The routing decision is affected by the node residual energy information which is taken as a routing metric where the route with maximum residual energy node received at the destination is selected.

In [6], the authors developed a multi-rate AODV that showed better throughput and performance than AODV. The design is based on the received signal strength (RSS) shared between the physical and routing layers. The RSS is used to compute the path loss which serves as a routing metric in the protocol. As the selected route is the one with the least path loss, which nearly means less interference, the protocol can induce minimum bandwidth consumption.

In [7], the focus was on the multi-rate communications handling problem of the traditional AODV protocol. The authors proposed a protocol called Multi-Rate AODV (MR-AODV) that establishes more efficient routes in wireless multi-rate environments. This protocol uses the path gain as a routing metric to select the best path between the source and the destination. Simulation results showed an improvement in the network throughput. As the number of nodes or the distance increases, the protocol shows better performance compared to AODV, this is due to the efficient route selection algorithm implemented. In contrast, the route discovery process takes more time than that of the traditional AODV.

In [8], the authors developed mobility adaptive cross layer design that improves the performance of AODV by coupling the route discovery process, the RSS information, and the mobile node speed to establish stable and optimum routes. The design allows better network resource utilization by decreasing the routing failures and overheads, and reduces the route failures and routing overhead in very dense networks.

3. Cross Layer Design Proposal

3.1 Preliminaries and network design

The proposed TAODV is a modified cross layer design version of the well-known AODV routing protocol. The modification considers route selection engineering process. The proposed cross layer design relies on information (remaining energy, RSS and remaining queue length) that can be obtained from lower layers as illustrated in Figure 1. On the other hand, routing packets headers are changed by adding new fields; routing packets forwarding algorithms are modified and the route selection algorithm at the destination is completely enhanced as depicted in the following sections.

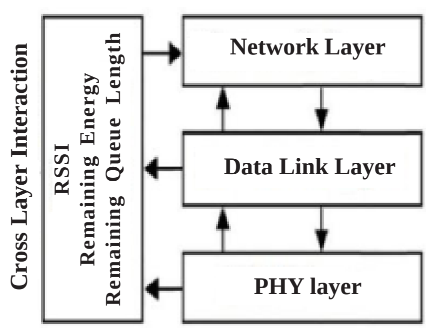


Figure 1. Proposed cross layer design

3.2 Route request and route reply modifications

First, the route request packet (RREQ) in the routing protocol is modified. There are two reserved fields in the RREQ packet of the traditional AODV protocol. These fields are used in TAODV; one is used to store the remaining queue length and the other is used to store the remaining energy value at the current node. Also the Route Reply packet (RREP) is modified. There are two reserved fields in the RREP packet of the traditional AODV protocol. Only one of these fields is used in TAODV to store the weight of the weakest hop across the selected route.

3.3 TAODV route selection metric

The chosen routing metric combines the received signal strength measured upon RREQ reception, the node's remaining energy and the remaining queue length of the previous node obtained from the forwarded RREQ. A certain weight is giving to each attribute in order to fine-tune the results with respect to the network scenario and user's requirements. The weight is expressed in Equation (1).

$$RREQ_{weight} = (\alpha * RSSI) + (\beta * RE) + (\gamma * RQL) \quad (1)$$

$$\text{where } \alpha + \beta + \gamma = 1$$

RSSI represents the received signal strength percentage.

RE represents the remaining energy percentage.

RQL represents the remaining queue length percentage.

α, β and γ represents the weight associated to each attribute.

Converting RSSI from watt to percentage is done by transforming from watt to decibels mille watt (dbm) using the formula given in Equation (2):

$$RSSI_{dbm} = (10 * \log_{10}(RSSI_{watt})) + 30 \quad (2)$$

Then, we compute the strength percentage of RSSI as given Equation (3) with respect to [9].

$$RSSI_{percentage} = 100 - 80 * \frac{(PerfectRSSI - RSSI_{dbm})}{PerfectRSSI - WorstRSSI} \quad (3)$$

Where PerfectRSSI = -20 dbm and WorstRSSI = -85 dbm

Converting the remaining energy value from Joules to percentage and the remaining queue length value from bytes to percentage are done using the following two consecutive equations:

$$Remaining\ Energy_{percentage} = 100 * \frac{Remaining\ Energy}{initial\ Energy} \quad (4)$$

$$Remaining\ Queue_{percentage} = 100 * \frac{queued\ packets}{max\ queue\ size} \quad (5)$$

3.4 RREQ and RREP forwarding algorithms

The RREQ forwarding algorithm is shown in Figure 2. After sending the RREQ by the source, the intermediate node receiving it for the first time calculates the reverse route weight according to the formula in Equation (1), caches it in its routing table entry, and then forwards this RREQ packet. If this packet is received again from another node in the network, the weight is re-calculated and a reverse route updating decision is taken. If the new weight is better than the cached weight, the reverse route and cached route weight are updated and the packet is dropped; else if the cached weight is better, the RREQ packet is immediately dropped. Then the node verifies whether it is the destination of the received RREQ or not. If so, the node sends back a route reply (RREP) to the source, else the algorithm is repeated.

The RREP forwarding algorithm is shown in Figure 3. When an intermediate node receives the RREP, it checks the value in the weakest hop weight field in the packet. If the value is zero, it is updated to be equal to the reverse route weight; else the value is compared to the node's reverse route weight. If the reverse route weight is greater, no changes are done, else the weakest hop weight in the RREP header is updated to be equal to the reverse route weight. Then the packet is forwarded.

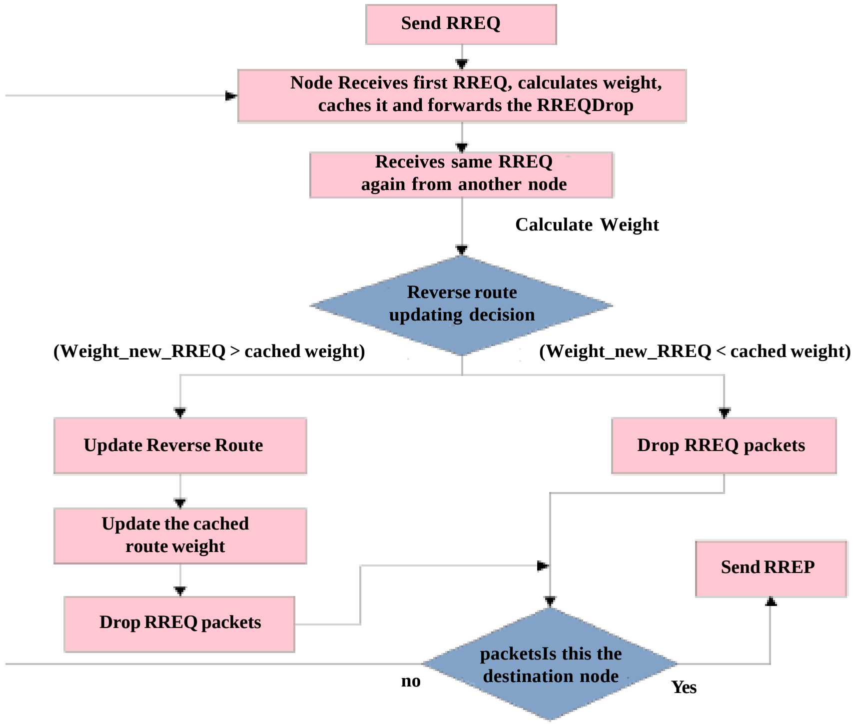


Figure 2. RREQ forwarding algorithm

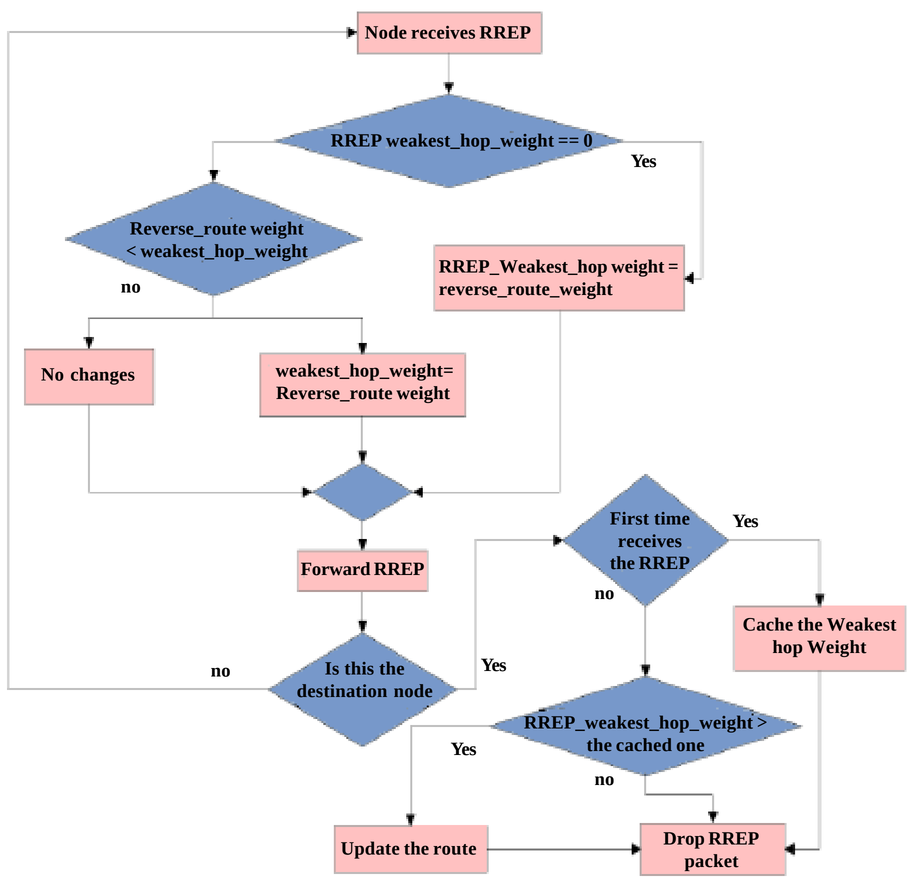


Figure 3. RREP forwarding algorithm

If the node is the destination and it received the packet for the first time, the weakest hop weight is cached and the packet is dropped. In case the node receives the same RREP again, a comparison between the packet's weakest hop weight field value and the cached weight is done, if the cached weight is smaller, the route is updated and the packet is dropped, else the packet is simply dropped.

When the RREQ message flooding starts propagating, the intermediate nodes cache the best received RREQ weight that has the highest RSS, remaining battery power and remaining queue length in order to get the most optimal reverse route which will be used by the RREP message to reach the destination. This strategy will lead to select the nodes that have the best connectivity with each other, and to decide about the most powerful nodes that can handle traffic and last longer before their energy resources are depleted. Therefore, this RREQ forwarding strategy will lead to avoid core nodes remaining energy depletion quickly by excluding route selection that contains nodes having poor remaining energy. Moreover, the algorithm will also lead to select the less congested routes and thus lessening the packets dropped by the interface queue.

For data transmission, the final selected route is the one with the best weakest hop weight. Thus, this route selection mechanism allows avoiding routes that contain weakest nodes which may break the selected path, thus extending the links' life between the source and the destination.

4. Performance Study

We are interested in studying the performance of the following parameters:

- Throughput: defines the data packets correctly delivered to the destination, i.e. the total number of packets received by the destination per unit time.

- Average end-to-end delay: defines the average total delay including the propagation delay, queuing delay and retransmission delay of lost packets.

- Routing overhead: defines the overhead encountered due to the transmission of the routing packets. It is mathematically defined as the total number of routing packets over the total number of routing and data packets.

- MAC overhead: defines the overhead encountered due to the transmission of MAC layer packets. It is mathematically defined as the total number of MAC layer packets over the total number of MAC layer and data packets.

- Normalized Routing Load (NRL): defines the average number of routing packets transmitted for each data packet. It is mathematically defined as the number of routing packets over the data sent or received depending if we are measuring NRL at the receiver or at the sender.

- Packet loss: defines the percentage of packets dropped by a mobile node.

- Packet delivery fraction (PDF): defines the percentage of the data packets sent to the data packets received.

- Dropped IFQ packets: defines the number of packets dropped by the interface queue (IF) of the router when it is full.

4.1 Simulation environment and parameters

Table I summarizes the parameters used for the simulation. Moreover, we used the two ray propagation model on the physical layer, and the Random Waypoint mobility model to simulate the mobility of nodes. We seeded each simulation between 5 and 10 times and then averaged the results. We used VBR (Variable Bit Rate) and CBR (Constant Bit Rate) traffic to give a fair evaluation. The weight values were set to $\alpha = 0.6$, $\beta = \gamma = 0.4$.

4.2 VBR traffic simulation

For this set of simulations we chose the following set of parameters: 80 mobile nodes, VBR (FTP) traffic, maximum speed 10m/s. TAODV has less routing overhead than AODV as shown in Figure 4. Such results were expected since TAODV selects more stable routes. More stable routes have extended life time which leads to decrease the number of the rebroadcasted RREQ messages that are sent when the route is broken. TAODV has also less MAC overhead as seen in Figure 5. That's due to decreasing the number of MAC control packets sent, since the choice of less congested routes leads to lessening packets collisions. A node receiving packets from many neighbor nodes suffers from packet collisions more than a node receiving packets only from one neighbor.

Parameter	Value
Number of nodes	40 – 80
Size of the network	700m x 700m
Transmission power of nodes	200 mw
Pause Time	0 – 200 sec
Interface queue size	64 bytes
Initial energy of nodes	30 Joules
Time of simulation	200 sec

Table 1. Simulation Parameters

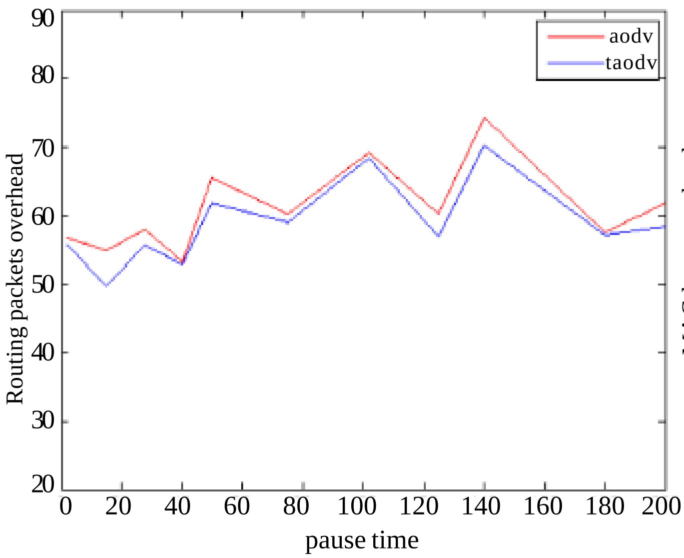


Figure 4. Routing overhead vs pause time

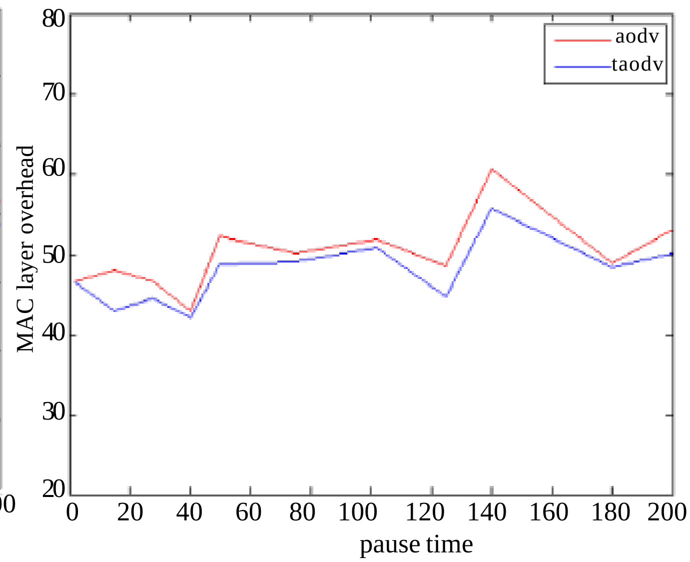


Figure 5. MAC overhead vs pause time

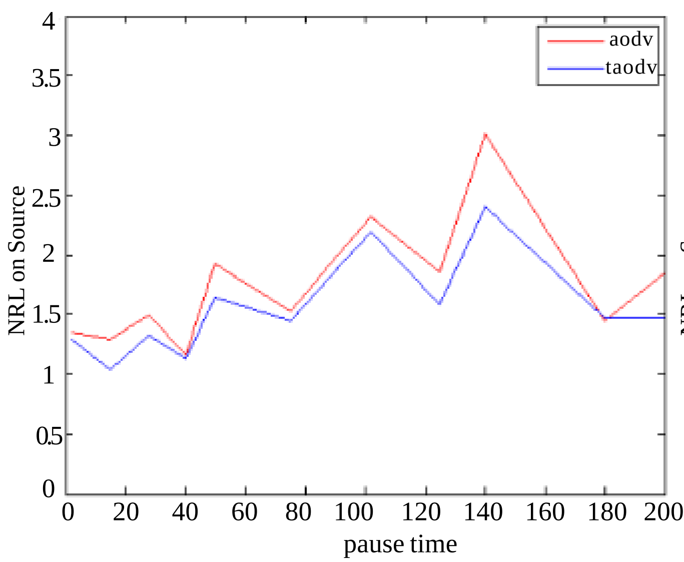


Figure 6. Normalized routing load vs pause time

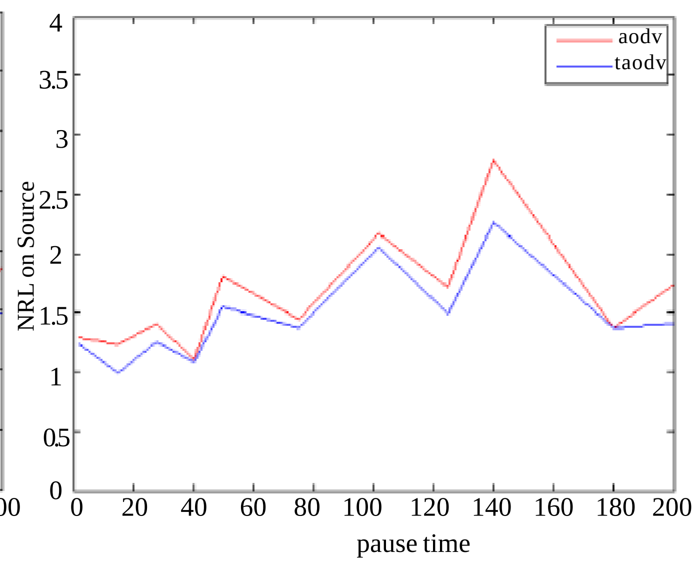


Figure 7. Normalized routing load vs pause time

TAODV shows less NRL than AODV as seen in Figure 6 and Figure 7. NRL is correlated with the route change, so as routes change NRL increases and vice versa. Since TAODV chooses more stable routes, it decreases the number of routes changes due to extending the route life time.

TAODV almost always has a better PDF as seen in Figure 8. Since we take into consideration the queue size in electing routes, then we choose less congested routes thus lessening the number of packets dropped by the IFQ. This will certainly increase the ratio of the received packets with respect to the transmitted packets.

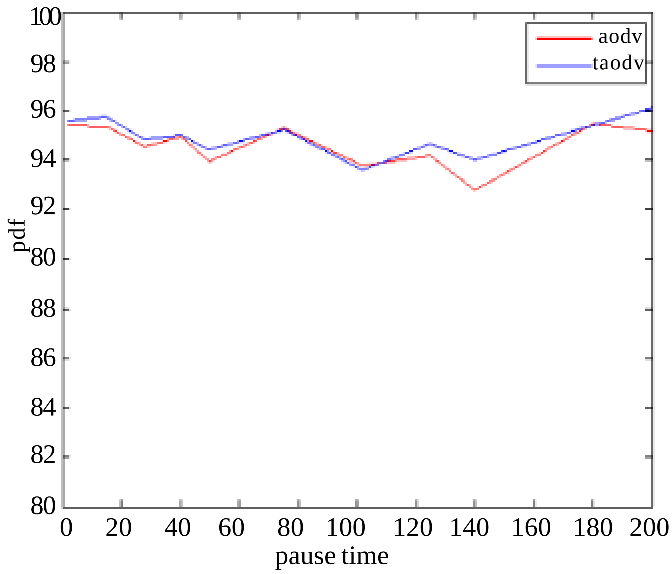


Figure 8. Packet delivery fraction vs pause time

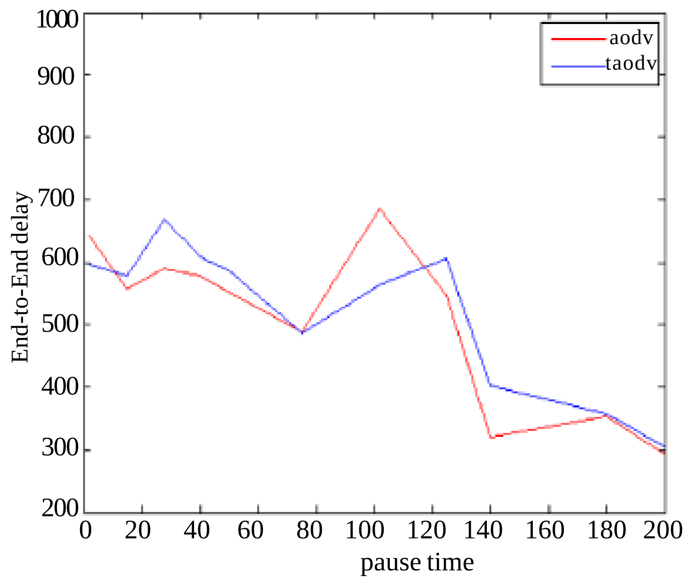


Figure 9. End-to-End delay vs pause time

TAODV shows increased end-to-end delay compared to AODV as seen in Figure 9. This is because AODV uses shortest hop count metric for path selection which will result in selecting paths having less propagation delay which will decrease the end-to-end delay. However, sometimes the queuing and retransmission delays are very long which will lead to bad results in AODV as showed at 0 and 100. However, for FTP traffic end-to-end delay is not a critical factor as in the case of voice/video data since users can tolerate more delays for receiving their files.

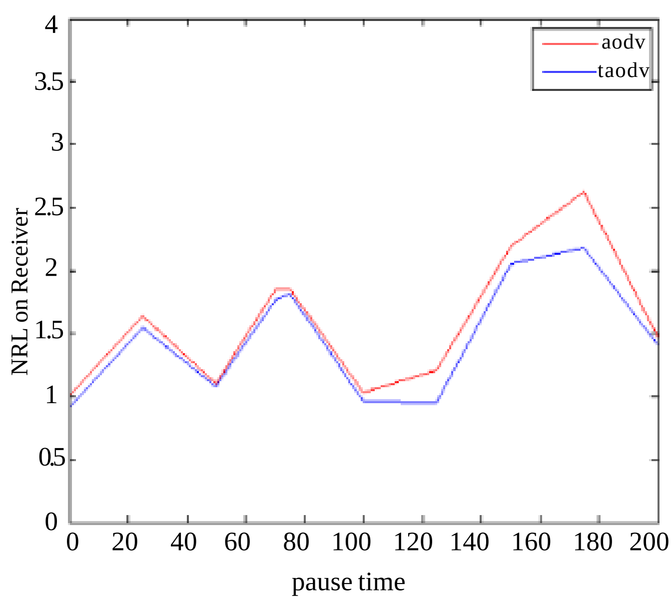


Figure 10. Normalized routing load vs pause time

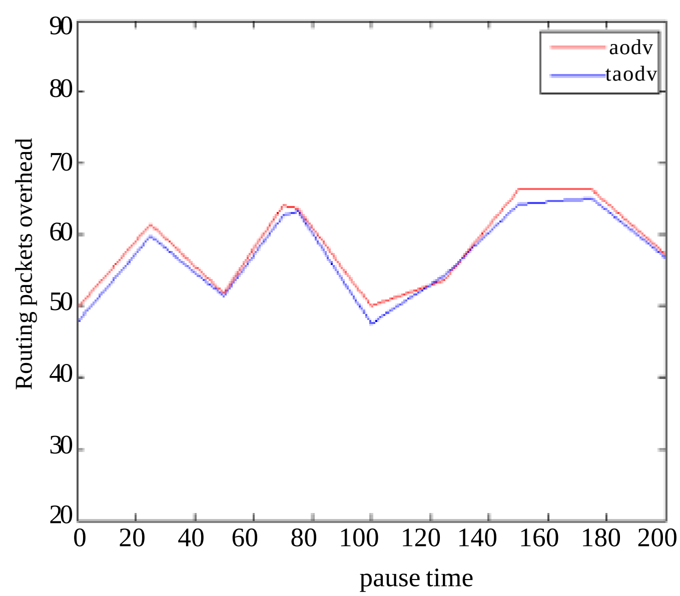


Figure 11. Routing packets overhead vs pause time

4.3 CBR traffic simulation

For this set of simulations we chose the following set of parameters: 40 mobile nodes, CBR (UDP) traffic, maximum speed 20m/s. TAODV shows less NRL than AODV as seen in Figure 10. Since TAODV chooses more stable routes, it decreases the number of routes changes due to extending the route life time. Moreover, the NRL is highly decreased by TAODV when the mobility degree decreases (pause time greater than 100).

TAODV has less routing overhead than AODV as shown in Figure 11. Such results were expected since TAODV selects more stable routes which have extended life time. This leads to decreasing the number of the rebroadcasted RREQ messages that are sent when the route is broken. However, due to the random nature of the simulation, TAODV may not perform better than AODV as we can see at pause time equal to 125 sec.

TAODV has also less MAC overhead as seen in Figure 12. That's due to decreasing the number of MAC control frames sent.

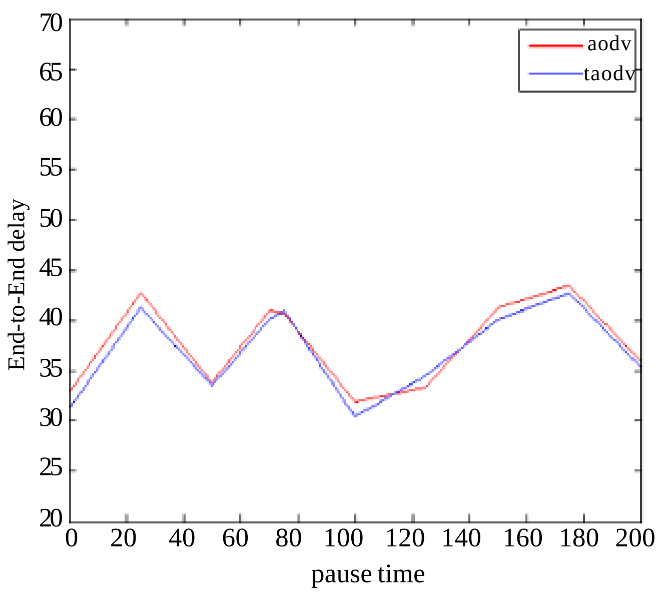


Figure 12. MAC packets overhead vs pause time

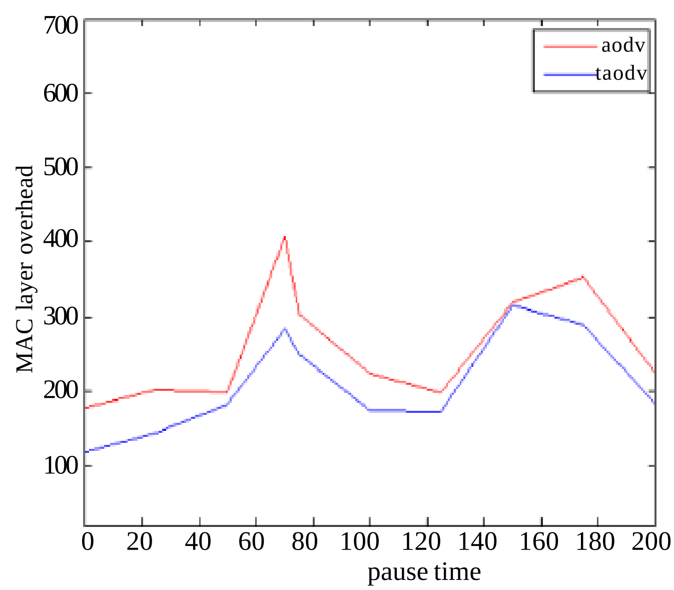


Figure 13. End-to-End delay va pause time

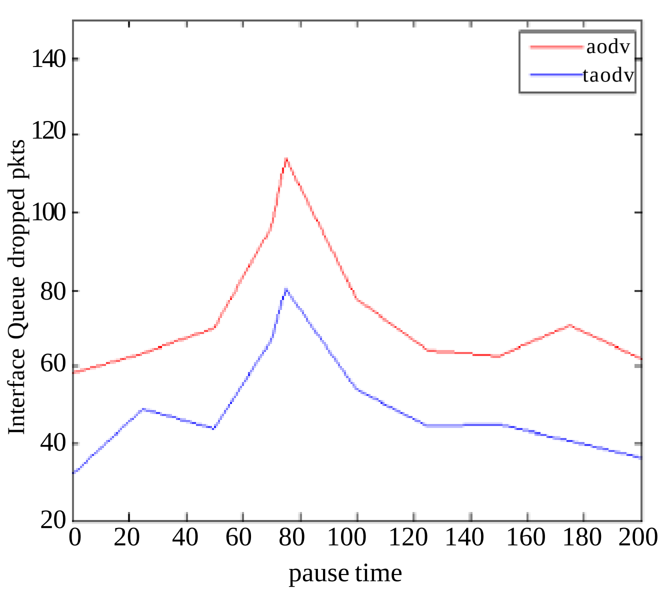


Figure 14. Interface queue dropped packets vs pause time

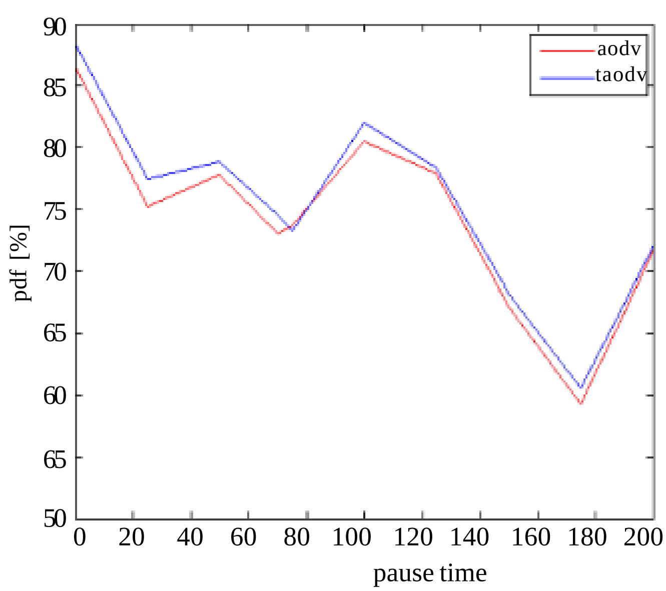


Figure 15. Packet delivery fraction vs pause time

In Figure 13, TAODV has always less end-to-end delay compared to AODV. That is due to the fact that for CBR traffic (voice), the rate is constant and many nodes queues will be saturated after a certain time which will introduce high end-to-end delay if paths with saturated queues are chosen. TAODV will avoid choosing paths having saturated queues due to its cross layer design. Moreover, TAODV will lessen the number of retransmission delays at the MAC layer since it will decrease the number of packet collisions as illustrated in Figure 12.

The number of packets lost at the interface queue (IFQ) of the node is always minimized in TAODV as we can see in Figure 14. This is due to the fact that TAODV avoids choosing routes having saturated queues.

TAODV seems to have better PDF as seen in Figure 15. Since, we take into consideration the queue size in electing routes; therefore less congested routes are chosen thus lessening the number of packets dropped by the IFQ. Lessening the dropped packets number will increase the ratio of the received packets with respect to the transmitted packets.

5. Conclusion and Future work

In this paper, we proposed a new protocol called Turbo-AODV (TAODV) to enhance the routing operation in MANETs. Experimentally we evaluated the performance improvements by simulating the proposed TAODV and AODV routing protocols under different types of traffic and mobility conditions. The simulation results have shown that the cross layered AODV may reduce the routing overhead, the normalized routing load and the interface queue dropped packets. Moreover, the results obtained show that the used variables in the physical layer (RSSI), and in the MAC layer (remaining energy, and the remaining queue length) can improve the network performance if they are used in the right place. High RSSI can provide routes containing nodes having better connectivity degree between each other, higher remaining energy can provide links having increased life time, and higher queue length can increase the packet delivery ratio by decreasing the number of packets dropped by the mobile nodes queue. Hence using the cross layer information from the physical layer and the MAC layer in the route discovery operation improves overall performance.

TAODV routing protocol can be enhanced by benefiting from the cross layer information not just in selecting better routes from sources to destinations but also for acting before the routes break. Hence what could be done is to identify links that will break before they break. A node receiving packets from a previous node in a certain path must always monitor the RSSI and the remaining energy of the previous node based on the received packets; when the RSSI or remaining energy reaches a threshold, the node should send to its previous hop a control packet which will initiate sending-back a message to the source like route error message without stopping the packets forwarding, indicating to start another RREQ. When a new route is found, the source can update its route entry and start sending using the new route. Another, exploitation to the cross layer information can be by adaptively adjusting the rate between two nodes in certain path between the source and the destination. Upon buffer saturation, a node that is forwarding received packets in a certain path can send a message to the nodes forwarding packets to it asking for reducing their packets transmission rate and thus lessening the number of dropped queue packets.

References

[1] Hosseini, Seyed Ali., Farrokh, Hamid (2010). The Impacts of Network Size on the Performance of Routing Protocols in Mobile Ad-Hoc Networks, *In:* PACCS, Beijing, China, p. 18-22.

[2] Rahman, Arafatur., Anwar, Farhat., Naeem, Jannatul., Abedin, Sharif Minhazul Md. (2010). A Simulation Based Performance Comparison of Routing Protocol on Mobile Ad-hoc Network, *In:* International Conference on Computer and Communication Engineering (ICCCE), Kuala Lumpur.

[3] Adam, N., Ismail, M. Y., Abdullah, J. (2010). Effect of Node Density on Performances of Three MANET Routing Protocols, *In:* International Conference on Electronic Devices, Systems and Applications(ICEDSA), Kuala Lumpur, p. 321 – 325.

[4] Suresh Kumar, Rathy, R. K., Pandey, Diwakar . Traffic Pattern Based Performance Comparison of Two Reactive Routing Protocols for Ad Hoc Networks Using NS2. *In:* 2nd International Conference on Computer Science and Information Technology(ICCSIT), Beijing , p. 369 – 373.

[5] Ghada, K., et al. (2008). Cross Layer Approach for Energy efficient Routing in WANETs, IEEE, p. 10.

[6] Amel, B., Zoulikha, M. (2009). Routing Technique with Cross Layer Approach in Ad Hoc Network, IEEE, p. 6.

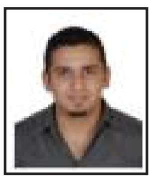
[7] Rahman, M., et al. (2008). A Routing Protocol for Multi-Rate Wireless Ad Hoc Networks: Cross Layer Approach, IEEE, p. 5.

[8] Ramachandran, B., et al. (2008). Mobility Adaptive Cross Layer Design for Reliable Route Discovery in Ad Hoc Networks, IEEE, p. 5.

[9] (2011, May) College of Engineering and Science at Clemson University. [Online]. http://www.ces.clemson.edu/linux/dbm-rssi.shtml.

Author Biographies

Dr. Zouhair El-Bazzal received the BS degree in Computer Science from the Lebanese University, Beirut, Lebanon in 2000, the MS degree in telecommunication networks in 2002 from the Ecole Superieure des Ingenieurs à Beirut, Saint-Joseph University, Lebanon, and the Ph.D. degree in engineering in 2008 from the Ecole de technologie superieure, Montreal, Canada. Previously, He worked as a lecturer in Montreal, Canada and as a Researcher and developer at Ericsson Canada Inc. Since 2010, Dr. Bazzal is an Assistant Professor in the School of Engineering, Department of Computer and Communications at the Lebanese International University, Lebanon. His main research interests are: wireless networking and communications, Long Term Evolution (LTE) in 3GPP, IP mobility, load balancing, admission control, and development of Policy and quality of service tools for LTE.



Khaldoun El-Ahmadieh attained his Computer and Communication Engineering degree from Lebanese International University in 2011. Since 2011, he is working as a system and network engineer in American Education institute university campus management division. Eng. Khaldoun is also a CISCO certified network / security associate, certified ethical hacker, Microsoft certified professional and Linux+ certified professional. His research interests are in the area of wireless communication especially adhoc networks, wireless sensor networks and network security.

Dr. Ali Chamas Al Ghouwayel received his B.E. degree in Physics-Electronics in 2002 from the Lebanese University, Beirut, his B.E. degree in Electronics Engineering and his M.S. Degree in Telecommunications in 2004 from the National School of Engineering of Brest, France, and his PhD in Signal Processing and Telecommunications in 2008 from the High School of Electricity and University of Rennes 1, Rennes, France. In 2008, He joined the Lab-STICC laboratory in Lorient, France and worked as a Post-Doctoral researcher on the European Project DAVINCI. Since 2010, Dr. Al Ghouwayel is an Assistant Professor in the Department of Computer and Communications at the Lebanese International University. His current research interests include Study, Optimization, and Adequation Algorithm-Architecture for Hardware Implementation of Non-Binary LDPC decoders.