Performance Evolutions of Velocity-Aware Routing Protocol for Mobile Ad hoc Networks

Muneer O. Bani Yassein, Alaa N. Alslaity
Department of Computer Science
Jordan University of Science and Technology,
Irbid 21100, Jordan
masadeh@just.edu.jo, analslaity08@cit.just.edu.jo

Ismail M. Ababneh
Department of Computer Science
Al al-Bayt University
Mafraq 25113, Jordan
ismael@aabu.edu.jo

Abstract— **In recent years, Mobile Ad hoc Networks (MANETs) became an attractive research target. Several protocols were proposed to facilitate the vital operations of such type of Networks. Many routing protocols have been proposed in the literature, as routing operation is considered as one of the most important procedures used in MANETs. Among the so many protocols, on-demand routing protocols are of major contribution to handle the routing operations effectively. Ad hoc On-demand Distance Vector Routing protocol (AODV) stands to provide an excellent example of the on-demand routing protocols. AODV corresponds to the unique nature of MANETs by incorporating several features for discovering and initiating paths on an on-demand fashion, reducing both control and processing overhead, providing a multi-hop routing capability and maintaining the dynamic topology. Nevertheless, many opportunities for further improvements are still possible. In this paper, we attempt to incorporate mobility-aware features along with the AODV routing protocol features so as to handle mobility encountered by mobile nodes, to improve the performance and to add some promising capabilities. Our suggested protocol computes the node mobility periodically and uses this computed value to make useful routing decisions thereafter. Simulations are done using GloMoSim 2.03 simulator. According to the results, our proposed protocol proves its superiority over the original AODV protocol in terms of the reduced overhead and the increased packet delivery ratio.**

Keywords-Mobile Ad hoc Networks (MANETs); Routing; AODV; Mobility; Velocity Awareness.

I. INTRODUCTION

A Mobile Ad hoc Network (MANET) is a group of mobile nodes that communicate and collaborate with each other without the need to any means centralization or pre-existing infrastructures. Due to the lack of the centralized access points, the mobile nodes are required to act as both hosts and routers and the same time to perform the routing process properly. Mobile ad hoc networks can be used in numerous situations and can provide tremendous opportunities, particularly if there is a need for establishing a network for a limited period of time in a location where wired infrastructure is nonexistent or very difficult to deploy. The applications of MANETs include search and rescue operations, academic and industrial applications, and Personal Area Networks (PANs).

Compared with the other types of networks, MANETs have the following exclusive characteristics: bandwidth and transmission rate limitations, energy constraints and dynamic topology [9].

Mobile ad hoc networks, as the name indicates, are mainly characterized by the dynamic topology due the mobility of nodes, hence, the name “Mobile”. There are no restrictions on nodes mobility and nodes are free to move any time towards any direction and at any speed [2]. In addition to mobility issues, a MANET has security and energy constraints as well as bandwidth limitations.

In our work, we concentrate basically on mobility considering it as a major factor in MANETs that affects the overall performance of the network. This is because the frequent and high mobility of nodes can cause frequent link breakages, resulting in a less reliable routes and a more route re-initiation. The extra route discovery process requires more Route Request Packets (RREQ), Route Reply Packets (RREP), and Route Error Packets (RERR) [3], this in turn, leads to more control packets overhead.

The primary objective of this paper is to take the previously mentioned limitations into consideration to design and implement a stable and overhead efficient routing protocol. The proposed protocol concerned mainly on the network overhead caused due to the usage of uncontrolled flooding and that caused due to the mobility nature of MANETs. In this protocol, nodes calculate their mobility periodically and use it mainly to establish a reliable route towards the destination during route discovery process. Simply put, a reliable route is the one with low mobility, yet; low probability of failure.

The rest of this paper is organized as follows: Section 2 overviews the state of the art works in mobility aware protocols. Section 3 illustrates our proposed protocol and the methodology of quantifying mobility. The simulation environment and the experimental results are discussed in Section 4. Finally, Sections 5 concludes the paper and provides our future directions.

II. RELATED WORK

Mobility is considered as one of the main challenges in MANETs. In [4], link duration is proposed as mobility metric to evaluate the overall network mobility status. The authors defined link duration as the time period during which two mobile nodes remain within the transmission range of each other. They used this metric as a major clue to indicate network performance, because long-lived links increase network stability.

Idrees et al. [5], proposed a mobility-aware scheme such that Hello Packets were used to enhance mobility awareness in the AODV. Upon receiving a Hello Packet, along with the assistance of the GPS coordinates of the source node, a lightweight mobility aware agent on each node of the network compares these coordinates with previous ones and then can determine information about the mobility of the originator node. When a node receives a RREQ packet and needs to send a RREP (it is either the destination or it has an active route to the desired destination), it will use the mobility awareness to choose the best neighbor which is not moving frequently. This process of selecting a best neighbor is done at each intermediate node. As a result, a path with the maximum number of low mobile nodes is established between source and destination.

In their proposed work, Qin et al. [6] considered three parameters that are used for monitoring the mobility status by individual nodes. These parameters are: node degree, average link duration and number of link breakages. These parameters can be obtained by “hello” messages exchange and they assist each node in sensing the status of its neighbors. In addition, a node can know how many links may be broken if it has not received “hello” messages from the previously connected nodes within some period of time, and then it can calculate the link duration for each broken link, and the average link duration at the moment. In order to examine the effect of the three proposed parameters, they are deployed and monitored at different mobility levels and with different mobility models.

Liang Q and Thomas [6] observed that the number of link breaks obtained by a node has nearly linear relationship with node mobility, which is defined as the relative speed between two nodes. The correlation is based on the average of all the nodes in the network, and the value of this metric fluctuates significantly for each node during the simulation.

In [7], Enneya et al. proposed a mobility-aware method to improve the performance of AODV. They define mobility metric and used it in both route discovery and route maintenance. In route discovery, the hop-count metric that is used in standard AODV is dropped, and it is replaced with a combination of two mobility parameters: average and mean of the “calculated mobility” along the path between any source node and destination. Consequently, more stable routes were obtained. In route maintenance, the local repair mechanism was extended in order to avoid the RERR packets by allowing the node that detects a broken link to choose an alternative route based also on the mobility metric. This affects the overall overhead of re-initiating the route discovery process and also reduces the use of RERR packets.

III. METHODOLOGY

Mobility is of a major importance factor in the ad hoc networks environments. Depending on the nodes’ mobility level, the overall network topology can be described. That is, if nodes are of low mobility and change their physical location seldom, then the network topology is said to be stable (or semi-stable). However, if nodes move very rapidly, then no expectation can be made on the network topology because what holds true for a specific period of time cannot be guaranteed to still true at the time after. Through the literature, it is shown that the majority of ad hoc routing protocols are incapable to handle high mobility.

In the literature, there are many mobility metrics that are used to quantify nodes mobility [7]. In our approaches, we depend solely on the locally available topological information, such that the change in the (x, y) coordinates for a particular node provides a good indication of the network movement pattern and mobility.

This section provides a detailed discussion of our proposed protocol and the contribution it adds over the traditional AODV protocol.

A. Our Protocol

In our work, we propose a Velocity-aware Ad hoc On-demand Distance Vector (VA-AODV) protocol that is capable to periodically compute mobility and make useful routing decisions accordingly. Our VA-AODV protocol offer major contributions and improve the performance of the original AODV protocol.

Unlike the AODV, wherein, the source node broadcasts the RREQ message to all its neighboring nodes (regardless to their mobility status) for the sake of finding the intended destination node, our VA-AODV protocol takes into consideration the mobility of neighboring nodes and picks the nodes with lower mobility to perform the route discovery process. In other words, in our VA-AODV, each node computes its own mobility periodically (i.e., every HELLO_INTERVAL). Then, broadcasts the value of its own mobility along with the HELLO message to inform its neighbors about its mobility status. Each node in turn, updates its neighbor table by adding ascending-ordered entries of (node ID, velocity) pairs for all neighbors, such that the ascending order is based on nodes’ velocity.

In VA-AODV, when a source node wishes to communicate with a destination and it does not have a route to that destination, it initiates a route discovery process by referring to its neighbor table and picking a set of nodes with lower velocities to participate in the route discovery process (instead of choosing the whole neighbors, as the case in AODV).

We refer to the selected set of neighbors, which will participate in the route discovery process as the *CoveringSet*, and it is defined as the set of 1-hop neighbors that cover the overall 2-hop neighbors. The *CoveringSet* should satisfy two conditions; it should ensure full coverage for the 2-hop neighbors, and it should consist of the neighbors with lower velocities as much as possible. Building *CoverinngSet* is a distributed process in that each node builds its own *CoveringSet* independently.

The process of VA-AODV is done as follows: when a node (S) wants to communicate with a destination node (D) that is not within the transmission range of S, it firstly creates its *CoveringSet* using its neighbor table. Starting from the first entry in the neighbor table (remember that this table is sorted in an ascending order based on the velocity), S checks whether the current neighbor add additional coverage for some 2-hop nodes or not. If so, current neighbor is inserted to the *CoveringSet*, otherwise S continues with the next neighbor. This process repeated until achieving full coverage for the entire 2-hop neighbors regardless the number of nodes that are in the CoveringSet. Hence, the number of nodes participated in the CoveringSet are not defined in advance, rather it depends on the coverage condition (i.e., the CoveringSet should covers the entire 2-hop neighbors). Once node S finished building its CoveringSet, it appends this set to the RREQ packet and broadcast it to its neighbors, only those neighbors who's IDs included in the CoveringSet will relay the packet. The same applies for the intermediate nodes where they look their neighbor table up and decides which neighbors are allowed to relay the RREQ further. Therefore, the overall selected route is stable and more reliable.

B. *Velocity Quntfication*

In our VA-AODV protocol, we assume that each node is equipped with a GPS device from which it obtains its own (x, y) coordinates. The availability of position information as well as the continuous tracking of the changes in this information within a specific period of time t provides each node with the ability to calculate its own distance crossed during that time t, which can be used for the purpose of speed calculation.

To explain our velocity quantification methodology, let us denote the position of node i at time t as Pi,t which is actually obtained from the coordinates pair (xt, yt). Further, let the position of the same node at time t+α be denoted as Pi, t+ α which corresponds to (xt+ α, yt+ α), then the crossed distance for this node during the time period T = (t+α) – t is denoted as DT and is computed as given in equation 1:

$$Dt = \sqrt{(x_{t+\alpha} - x_t)^2 + (y_{t+\alpha} - y_t)^2} \qquad (1)$$

Because each node sends hello messages to its neighbors every HELLO_INTERVAL, it can calculate its velocity (or speed) at the end of each HELLO_INTERVAL and append the value of speed with the hello message. In other words, let ε be the HELLO_INTERVAL time, and given the crossed distance DT, then the velocity Vε of node i during the period of time T can be calculated as follows:

$$V_\varepsilon = \frac{Dt}{\varepsilon} \qquad (2)$$

Upon receiving the hello message, each recipient node updates its neighbor table such that a new entry will be added for the originator of the hello message if it does not already exist. The added entry will be of the form <nbrAddr, Vε>, where Vε is the velocity (speed) at which the distance DT was crossed.

C. *Our Contribution*

Our Velocity-Aware Ad hoc On-demand Distance Vector (VA-AODV) routing protocol is designed to work in mobile ad hoc networks as an adaptive, decentralized and mobility-aware protocol that outperform the original AODV in the following aspects: First, the VA-AODV controls the route discovery process by selecting a set of nodes (with low velocity) to send (or relay) the RREQ messages, this in turn will reduce the control overhead associated with the traditional AODV. In addition, the nodes perform mobility quantification in a simple and distributed manner based on the locally available information about position changes. This in fact, provides very precise information about velocity. Our mechanism of mobility aware routing guarantees more stable and reliable routes since each node chooses only stable routes, this will decrease the number of broken links, and thus, reduces the number of reinitiating route discovery trials and reduces the number of dropped packets, as consequent, the packet delivery ratio is increased and the network overhead is decreased. In particular, our velocity-aware approach contributes mainly in terms of reducing the overall control overhead (since the number of relayed RREQ packets by intermediate nodes is reduced).

IV. PERFORMANCE EVALUATION

In order to evaluate the performance of our VA-AODV protocols, the proposed mechanism is simulated using GloMoSim 2.03 simulator [8]. The simulation environment and parameters are clarified in the subsequent sections.

A. *Simulation Environment*

The simulation area that is considered for simulations is 600 m × 600 m. The mobility of nodes is represented by the choice of a uniform speed between a minimum speed, vmin=0 and a maximum speed vmax, where vmax = 2, 5, 10, 20 and 40 m/s. this wide range of speeds used (from 2m/s up to 40m/s) is selected carefully to show us the behavior of the proposed protocol for any speed. The Mobility model used through simulation is the Random way point and the channel capacity is 2 Mbps. We aim to assess the behavior of VA-AODV in the dense networks, so that, and through empirical, all the experiments done using 40 nodes with 250m transmission range. Also we used the Constant Bit Rate (CBR) traffic generator, and the number of sources is set to be 24 nodes selected randomly and send to a randomly chosen different receivers. Each source generates 1 and 5 packets/seconds for different scenarios. The time for simulation is 300s and bidirectional link between each pair of adjacent nodes is considered. In the MAC layer (i.e., Data Link layer), we used the IEEE 802.11 communication protocol.

B. *Simulation Parameters*

We evaluate the performance of our proposed protocol using the following simulation parameters [11]:

- **Packet Delivery Ratio (PDR)**: the packet delivery ratio is a ratio of the correctly delivered data packets.
- **Routing Overhead**: the routing overhead ratio is the ratio of the network control packets sent to the correctly delivered data packets.
- **Saved Rebroadcasts (SRB)**: the saved rebroadcast represents the ratio of the number of route request (RREQ) packets retransmitted to the total number of route request (RREQ) packets received by any node [10].

C. *Simulation Results*

In this section, we provide a performance comparison between the AODV protocol and our proposed protocol, VA-AODV in terms of control overhead, PDR and SRB. The following scenarios show us the effects of speed with number of nodes equal 40 nodes; in the first scenario, each source node sends 1 packet/second (i.e., the traffic load= 1Pkt/s), while in the second one we used traffic load = 5Pkts/s.

Figures 1, 2 and 3 show the performance results for the control overhead, PDR and SRB, respectively for a number of nodes =40 and a traffic load of 1 packet/second. Figure 1 shows the superiority of our protocol over the AODV in terms of reducing the average control overhead. This is due to the fact that our protocol tends to control flooding by selecting only a subset of nodes with low mobility to retransmit packets. This reduction of retransmissions saves a lot of control packets (RREQ, RREP, and RERR) from being sent, and this reduces the overall routing overhead. The figure shows also that as the maximum speed of nodes increases, the overhead encountered by AODV increases as well. This is because the faster the node's movement speed, the less stable the links are, and the more the link breakages. The instability caused by high node speed requires sending more control packets (RREQs) needed for route re-initiation and (RERR) needed for local repair.

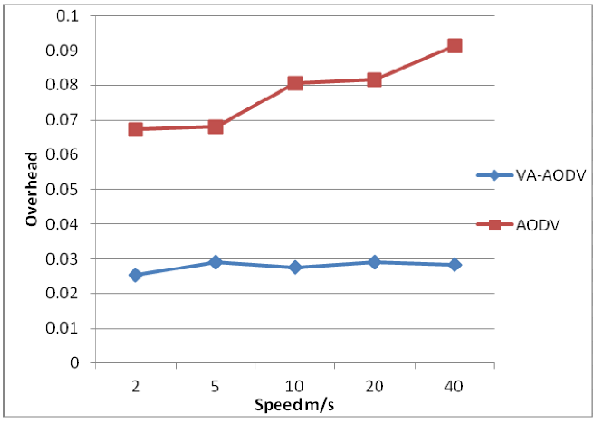

Figure 1. Average Overhead vs. Speed

The results in Figure 2 show that the Packet Delivery Ratio achieved by VA-AODV is much better than that of the AODV, especially for high speeds (20 and 40 m/s). This is expected because the velocity awareness of our protocol reduces the number of broken links by choosing the only stable nodes. This in turn guarantees a better delivery of packets.

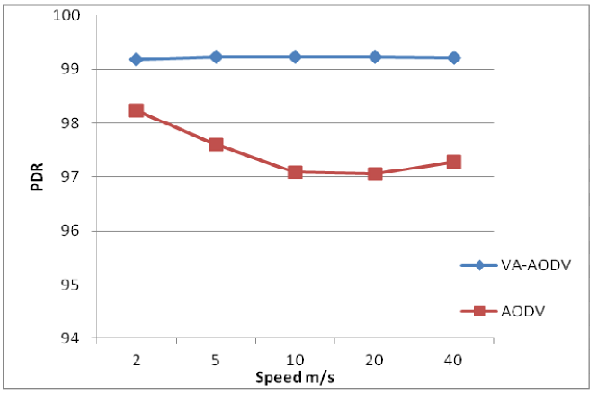

Figure 2. Average PDR vs. Speed

Figure 3 depicts the saved rebroadcasts achieved by our protocol in comparison with that achieved by AODV. As the figure shows clearly, our protocol significantly outperforms the AODV in terms of avoiding redundant retransmissions of the received packets. In addition, our protocol proves its stability and ability to save rebroadcasts even with high speed values, whereas the AODV protocol degrades clearly as the nodes speed increases.

 ISBN: 978-1-61208-236-3

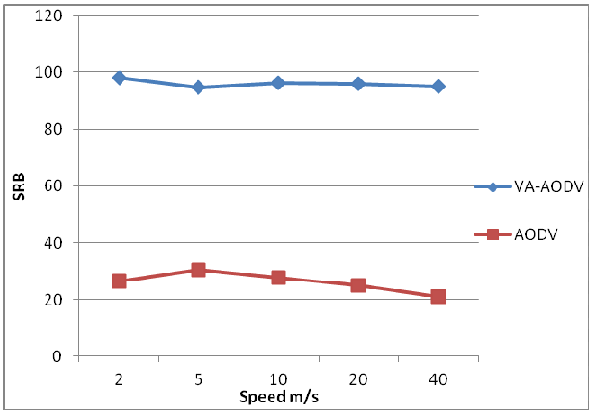

Figure 3. SRB vs. Speed

Figures 4, 5 and 6 show the performance results for the control overhead, PDR and SRB, respectively for a number of nodes =40 and a traffic load of 5 packet/second.

Figure 4 illustrates the superiority of our protocol over the AODV for all speed values. It can be inferred that with very low speed value (i.e., speed= 2m/s), the performance of both AODV and VA-AODV are almost similar, while the performance enhancement becomes evident for higher speed values.

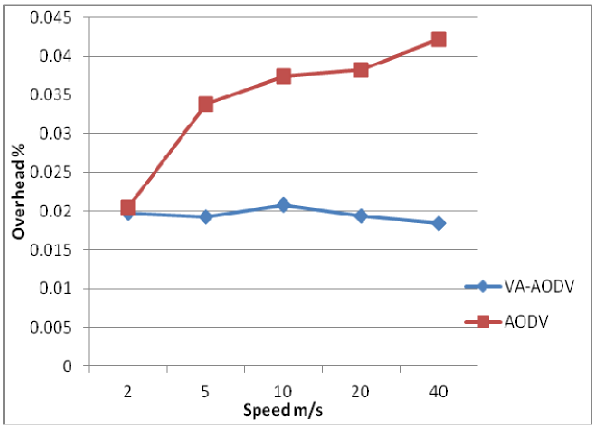

Figure 4. Average Overhead vs. Speed

Figure 5 shows that for different speed of nodes, and as the number of packets transmitted increases, the average packet delivery ration decreases for the AODV while it remains stable for our protocol.

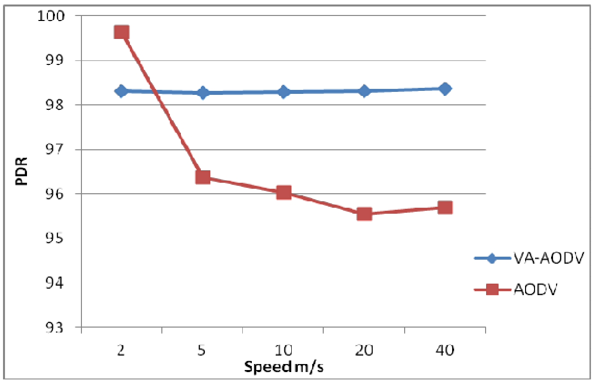

Figure 5. Average PDR vs. Speed

By varying the maximum nodal speed over a range of 2, 5, 10, 20, and 40 m/s and having and having a traffic load of 5 packets/second, it can be shown in Figure 6 that VA-AODV can achieve higher SRB when compared against AODV which uses blind flooding as a main mechanism for route discovery, thus redundant retransmission of packets occurred frequently.

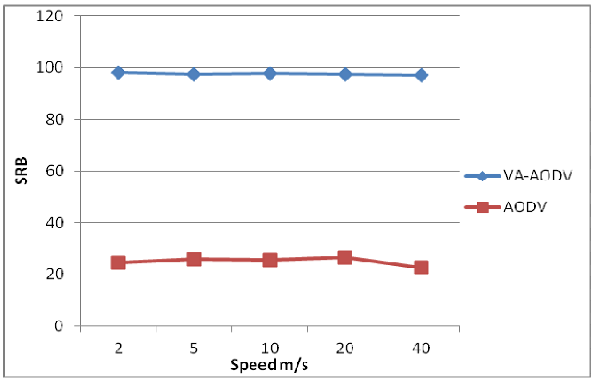

Figure 6. SRB vs. Speed

Based on the simulation results illustrated in this section, it is clear that our proposed VA-AODV protocol enhances the performance of the original AODV protocol in terms of reducing the control overhead; increasing the packet delivery ratio and increasing the saved rebroadcast. The VA-AODV significantly outperforms the AODV protocol in terms of reducing overhead by 69%. Regarding packet delivery ratio, the experiments show that our protocol outperforms AODV by 2.79%. Finally, our protocol achieves substantial improvement of the saved rebroadcast performance metric, such that the VA-AODV outperforms AODV by 77.86%. Moreover, the results show that VA-AODV ensures stability, in that it gives stable results for different speeds.

 ISBN: 978-1-61208-236-3

V. Conclusion and Future Work

In this paper, we proposed an ad hoc on-demand, velocity aware routing protocol that achieves significant enhancement over the AODV in terms of reducing the average control overhead, increasing the average packet delivery ratio and increasing the saved rebroadcast of packets. The proposed VA-AODV protocol depends on the change of a node's position during a specified period of time to calculate average node's velocity as mobility indicator in order to assist in making a proper routing decision. Taking nodes velocity (as a mobility metric) into consideration ensures a better routing performance in terms of decreasing control packets overhead, increasing packet delivery ratio and increasing the number of save rebroadcasted packets.

Although taking nodes velocity as a major factor for routing decisions gets better performance, it is not enough to depend on the node's absolute speed. There are three main parameters of the mobility; speed, position, and direction. In general, only one of these parameters is considered in selecting the next hop during the route discovery process [34]. Indeed, it is not sufficient to consider only one of these parameters as the only parameter for route discovery process. Thus, we should add other parameters (In addition to the velocity) to the algorithm in order to make it more precise and more reliable. Moreover, the proposed protocol needs more evaluation methods and simulations to ensure its superiority over other protocols.

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