New Velocity Aware Probabilistic Route Discovery Schemes for Mobile Ad hoc Networks

CONFERENCE PAPER · SEPTEMBER 2012

3 AUTHORS:

Mustafa Bani Khalaf
Hashemite University

Ahmed Yassin Al-Dubai
Edinburgh Napier University

Mourad Abed
University of Valenciennes and Hainaut-Ca…

New Velocity Aware Probabilistic Route Discovery Schemes for Mobile Ad hoc Networks

Mustafa Bani Khalaf, Ahmed Y. Al-Dubai and Mourad Abed*

School of Computing, Edinburgh Napier University
10 Colinton Road, Edinburgh, EH10 5DT, U.K.

E-mail :{ m.banikhalaf, a.al-dubai}@napier.ac.uk}
* UVHC, LAMIH, Universite de Valenciennes, France, F-59313 Valenciennes, France
E-mail: mourad.abed@univ-valenciennes.fr

ABSTRACT: *In this paper, we investigate efficient strategies for supporting velocity aware probabilistic route discovery in Mobile Ad hoc Networks (MANETs). MANETs usually use broadcast mechanisms to discover routes between nodes by flooding the network with RREQ packets. Usually, the routes of the high mobility nodes have frequent breakages which result in re-discovering the same routes frequently. Hence, uncontrolled RREQ packets can cause more channel contention and increase packets collision rate. This is well- known as the broadcast storm problem where different probabilistic solutions have been suggested to mitigate its side effect. To the best of our knowledge, this study is the first that considers the velocity vector probabilistic route discover in MANETs. Precisely, this study proposes a new Velocity Aware-Probabilistic (VAP) route discovery model, which can exclude unstable nodes while constructing routes between the source and its destination. Our simulation experiments confirm that our proposed model significantly outperforms existing well known solutions in terms of RREQ packet overhead and link stability.*

Keywords: Speed, Probability, Counter, AODV, Route Discovery, Broadcast problem.

1. INTRODUCTION

MANETs topology changes rapidly and frequently as nodes move freely with no restriction in terms of directions or mobility (i.e. speed and pause time). Data routing and packet dissemination is a challenging task typically for nodes that have high speed and different directions. Wireless links between such nodes experience frequent breakages and expired very often. Hence, re-establishing wireless connection requires flooding the network with a large number of control packets such as Route Replay Packets (RREP) and Route Error Packets (RERR), in addition to the extra RREQ packets. For instance, in Ad hoc On Demand Distance Victor (AODV) protocol [1], route discovery phase swaps the network with RREQ control packets to find the optimal route to the required destination. In some cases, the established route could contain unstable nodes, where link breakage is frequent and affect the overall network performance.

In MANETs the *broadcast storm* during the route discovery phase is a well-known problem [2], which occurs when uncontrolled broadcast mechanism is used to disseminate RREQ packets. Different broadcast mechanisms have been adopted in the literature to mitigate the broadcast problems [2] [3]. One of the most efficient suggested solutions is the probabilistic scheme which demonstrates better performance than other existing solutions. However, most of the suggested probabilistic schemes utilize network density [4], distance [5] or position [6] information, which is available with each node to adjust either the rebroadcast probability, counter threshold or the timer. Unlike other existing probabilistic solutions in this paper, we propose two new probabilistic schemes that utilize both sender and receiver velocity vector to calculate the cosine angle between them, and then to set rebroadcast probability, counter threshold and the timer accordingly. The main aim is to prioritize the transmission of the nodes with similar velocity in order to guarantee that only the most stable nodes participate in the route discovery phase, and to avoid the frequent link breakages phenomena. The rest of the paper is organised as follows. Section 2 introduces related work, problem statement and motivation. Section 3 presents a detailed description of the proposed schemes. Section 4 provides the performance evaluation of our algorithm. Finally, Section 5 concludes this study and outlines our future work.

2. RELATED WORK

A probabilistic scheme based on the network density information is suggested to mitigate the broadcast storm in AODV [4]. This scheme divides the nodes into four logical groups of density according to the maximum and minimum network density. The density information is collected by broadcasting HELLO packets every second to construct 1-hop neighbour list at each node. The node then decides in which groups it currently belongs to by comparing its neighbour list with the maximum and the minimum network density threshold $AVG_{threshold}$, which computed as follows:

$$AVG_{threshold} = \sum_{i=1}^{n} \frac{N_i}{n} \qquad (1)$$

Where n is the number of nodes in the network; N_i is the number of neighbours for node X.

Another variation of the density probabilistic scheme is suggested in [7]. In this scheme, rebroadcast probability is set according to the number of duplicated RREQ packets instead of the number of neighbours. Each node counts the number of the same received packet (i.e. c) within a random timer. Upon the timer expiration, the node uses the ratio between the total numbers of received packets (i.e. c) within the timer and the predefined Counter threshold (i.e. C), to rebroadcast the packet with the following exponential probabilistic function:

$$F(c) = e^{-\left(\frac{c}{C}\right)} \quad (2)$$

A distance based probabilistic scheme is suggested in [5] without neighbour knowledge information. It is called Weighted Probabilistic-Persistence Broadcasting (WP-PB) scheme. In this scheme when the node *j* receives a packet from node *i*, node *j* waits for a period of time WAIT-TIME and checks the packet ID and rebroadcasts with probability P_{ij} if it receives the packet for the first time; otherwise, it discards the packet. The rebroadcast probability is adaptively calculated according to the distance from the sender. When the timer expired the node rebroadcasts the RREQ packet with the last smallest value of probability as in the following formula:

$$P_{ij} = \frac{D_{ij}}{R} \quad (3)$$

Where D_{ij} is the distance between the sender and the receiver, and R is the average transmission range. To prevent the packet die out the node should wait further time and rebroadcast with probability equal to one.

A Position-Aware counter-Based scheme is proposed in [6], which combines the advantages of information source position and the number of duplicated RREQ packets. Each node has two pre-defined Fixed Counters (FC) value, and two Expected Additional Coverage (EAC) thresholds value. Each node upon receiving a broadcast packet, calculates the new additional coverage that can be covered. If the new additional coverage less than EAC_1 the node will not rebroadcast. Otherwise, the new additional coverage is larger than EAC_2 and a shorter timer is assigned for those nodes with a small FC value.

3.1 PROBLEM STATEMENT AND MOTIVATION

In the simple Fixed Probabilistic (FP) broadcast scheme, each node floods the network with pure probability P and cancels its transmission with P-1. To enhance pure probabilistic scheme, density threshold [4], a distance [5] and position-based concepts [6] were introduced. For example as in [4], a node cancels its retransmission if it has a density level above a predefined density threshold such as maximum network density. Another example as in [5], where the rebroadcast probability is calculated based on the distance between the sender and receiver. The probability of the receiver to cancel its transmission is high if it is just located close to the sender, but it is not related to stability. A basic Fixed Counter (FC) broadcast scheme [1] is a simple approach to suppress unnecessary nodes' retransmission based on local network density (i.e. number of copy) within the transmission range. This scheme works as follows: each node sets a random timer upon receiving RREQ packet. The node makes the rebroadcast decision blindly after timer expiration, and when the number of duplicated RREQ packet exceeds a predefined threshold. Otherwise, the packet is dropped. This scheme demonstrates better performance in a dense network in terms of high reachability and saved rebroadcast, typically when it augmented with other broadcast schemes [7]. However, it fails to construct a reliable route between source (s)/destination(s), since the velocity factor is neglected in this scheme.

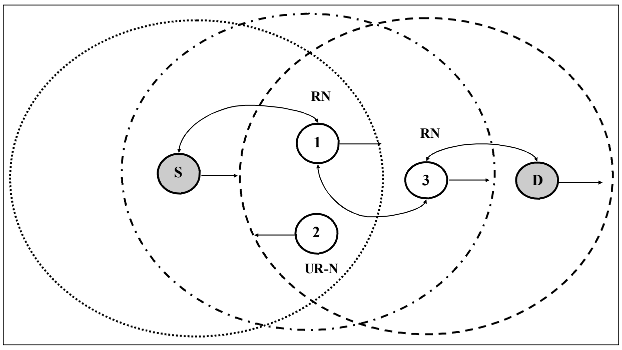

Figure 1: Example of RN and UR-N.

A probabilistic broadcast scheme should be designed in a reliable way in order to facilitate the data-packets delivery at a minimum overhead. The decision of selecting the node, that should undertake rebroadcast decision, plays an important role in the overall network performance. Hence, each node should calculate its rebroadcast probability carefully to avoid any unnecessary retransmission. To the best of our knowledge, existing probabilistic solutions do not include the velocity concept in order to set the most stable routes.

Motivated by the above discussions pertaining to the existing probabilistic schemes, we propose a new variation of the probabilistic scheme namely *Velocity Aware Probabilistic-based* scheme (VAP) which can mitigate the broadcast storm problem by improving the overall route discovery phase. This scheme adjusts both rebroadcast probability counter threshold, and timer adaptively at each node based on its velocity vector to construct the most stable path between any two nodes. The following section describes the proposed scheme.

3.2 VELOCITY AWARE PROBABILISTIC ROUTE DISCOVERY SCHEMES(VAP)

The node selection is a crucial part in designing the suggested scheme. Thus, in this investigation we classify all the mobile nodes into *Reliable Nodes* (RNs) and *Un-Reliable Nodes* (U-RNs) with respect to the velocity of the sender and the receiver node. Notice that RNs those have a relative similar velocity compared to the sender velocity are more likely to build the network routes. On the other hand, U-RNs are those nodes with velocities much different compared to the sender node velocity. Therefore, any retransmission by U-RNs should be suppressed in order to avoid early link failure and decrease overhead of routing packets. Before demonstrating the proposed schemes, we first describe the problem via the following example. Figure 1 illustrates the example of five nodes (S, 1, 2, 3 and D). Nodes 1 and 2 move with the same velocity of the Source node (S), where the node 3 and 4 move with a different velocity. A connection between node S and node D could be established via two routes: one via node 1 (route S-1-3-D) and the other via node 2 (route S-2-3-D). The first route is more likely to be stable compared to the second route as the node 2 moves with different velocity compared to the node S and node 3. Consequently, the selection of the second route is more likely to be invalid after a short time. By using information of the velocity vector, the cosine angle θ is calculated between the sender and the receiver to determine whether the receiver is RN or U-RN as in figure 2.

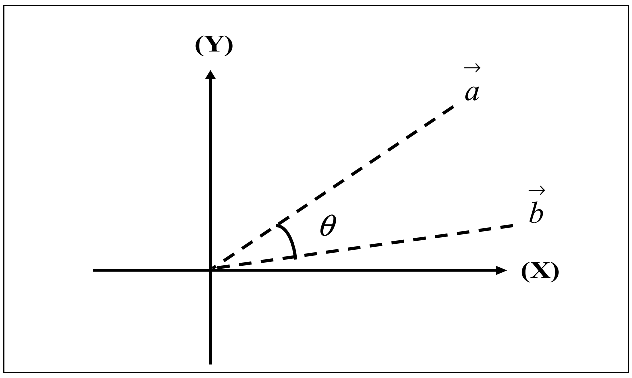

Figure 2: The value of cosine angle between two vectors

If the value of θ is less than the predefined angle threshold θ_{Th}, then the receiver is categorised as RN as it movies with the same velocity of the receivers. Otherwise, the receiver is categorised as U-RN. The angle θ is calculated using the following cosine equation Where $\vec{a}$ and $\vec{b}$ are the sender and the receiver unite vector information respectively:

:

$$\theta = \arccos \left[\frac{\vec{a} \cdot \vec{b}}{\left|\vec{a}\right| . \left|\vec{b}\right|} \right] \quad (4)$$

3.3 Simple Velocity Aware Probabilistic Route Discovery Scheme (SVAP)

The new proposed scheme helps to distinguish between RNs and U-RNs by assigning a different value for rebroadcast probability. A high rebroadcast probability is assigned for RNs, while a low value is assigned for U-RNs. This type of adaptation implicitly helps in establishing the most stable and reliable routes, and thus enhances the overall performance route discovery phase. This is can be noticed as *Simple Velocity Aware Probabilistic* route discovery scheme (SVAP) cuts off U-RNs, which causes frequent link breakage between nodes, which requires the source node to initiate a new route discovery session. The total net effect reduces the number of generated RREQ packet that causes the broadcast storm problem [1]. A brief outline of the SVAP scheme in shown in Figure 3 and it operates as follows.

- When the Source (S) node sends RREQ packet to find a destination, it adds its own velocity to the RREQ packet header. Once any Receiver (R) within the source transmission range receives the RREQ packet, it initializes a random timer and a Counter (C) to count the number of the received RREQ packet. Then, the cosine angle θ is calculated using equation (6) as given in Steps (1-10).
- After the timer expiration, the receiver is considered RN if the value of θ is less than the θ_{Th}, and is assigned a high Counter Threshold (C_{TH}=C_{HTH}). Otherwise, the receiver is U-RN and assigned a low C_{TH} = C_{LTH}. Steps (11-17).

SVAP: **Simple Velocity Aware Probabilistic Scheme**

```
IF (RREQ PACKET RECEIVED FOR THE FIRST TIME = TRUE) {
1:SV ←GET_SOURCE_VELOCITY ()
2:RV← GET_RECEIVER_VELOCITY ()
3: θ ←CALCULATE _GOSINE ANGLE()
4: θ Th←SET _GOSINE ANGLE_THRESHOLD()
5:TIMERRANDOM→ SET _RANDOM_TIMER()
6: WHILE (TIMERRANDOM != EXPEIRED){
7: IF (THE SAME RREQ PACKET RECEIVED) = TRUE{
8:GET_NUMBER _COPY() {C=C+1}
9:END_IF
10:  END_WHILE
11:IF ( θ < θ Th) = TRUE {
12: RS→SET_RELIABLE _NODE()
13:CTH→ SET_HIGH_COUNTERTHRESHOLD(CLTH)
14:  ELSE IF ( θ < θ Th) = TRUE {
15: RS→SET_UNRELIABLE _NODE()
16: CTH→ SET_LOW_COUNTERTHRESHOLD(CHTH)
17:END_IF
18: IF (C<CTH = TRUE){
19:P→SET_HIGH_REBROADCAST_PROBABILITY()
20:ELSE
21:P→SET_LOW_REBROADCAST_PROBABILITY()
22:  END_IF
23: RN←RANDOMNUMBER(0,1)
24: IF (RN<P = TRUE)
25: REBROADCAST_RREQ()
26: ELSE
27:  DROP_RREQ()
28: END_IF
```

Figure3: Description of SVAP scheme.

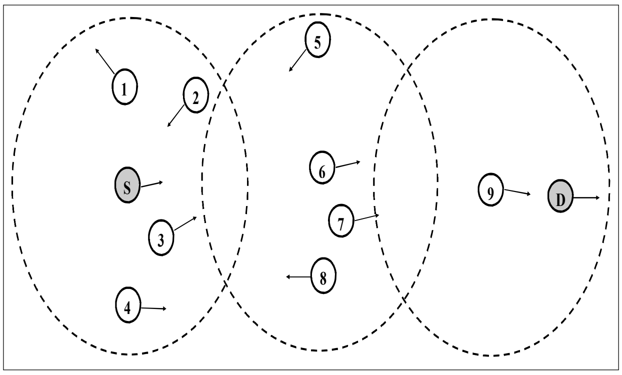

Figure 4: Example of both SVAP and AVAP.

- The receiver is RN, and is assigned a high rebroadcast probability, if the number of RREQ packet (i.e. C) is less than the pre-assigned counter threshold (i.e. C_{TH}). Otherwise, the receiver is U-RN and assigned a low rebroadcast probability. Steps (18-22).
- Finally, the algorithm generates a Random Number (R_N) between (0, 1); then a node rebroadcasts the RREQ packet if the R_N is less than the pre-assigned p. Otherwise the packet is simply dropped. Steps (23-28).

3.4 Illustrative Example

The following example illustrates the proposed scheme. In Figure 4, nodes 3, 4, 6, 7 and 9 are categorized as RNs since they have similar velocity compared to the Source (S) velocity. This means that the value of $\theta < \theta_{Th}$, and each node assigns a high counter threshold ($C_{TH} = C_{HTH}$). While nodes 1, 2, 5 and 8 are classified as U-RNs as they have different velocity compared to the source node S. This also means that the value of $\theta > \theta_{Th}$, and each node assigns a low counter threshold ($C_{TH}=C_{LTH}$). The value of C_{HTH} for the RNs and C_{LTH} for the U-RNs are adjusted to 2 and 1 respectively to control the rebroadcast decision. When the source node S sends a RREQ packet, nodes 1, 2, 3 and 4 initialize a random $TIMER_{RANDOM}$ and count the number of the same received RREQ packets. After the timer expiration, each node compares the value of Counter C with the value of C_{TH}, and takes a proper rebroadcast decision. In this scenario, nodes 1, 2, 3, and 4 upon receiving RREQ packet from node S, set the counter C=1. After a random period of time, suppose that the node 4 performs its rebroadcast first. Nodes 1, 2 and 3, receive this rebroadcast for the second time (i.e. C = 2), while nodes 5, 6, 7 and 8 receive it for the first time (i.e. C = 1). Nodes 1 and 2 assigned a low rebroadcast probability as the value of $C > C_{TH}$ (i.e. 2 > 1), while node 4 assigned a high rebroadcast probability as the value of $C < C_{TH}$ (i.e.) .In this way, any rebroadcast by nodes 1 and 2 are likely to suppress and implicitly excluded in constructing any route toward the destination. The same above steps are repeated in the nodes 5, 6, 7, 8 and 9. Nodes 6, 7 and 9 are privileged to participate in the route discovery process, which is not the case in nodes 5 and 8.

3.5 ADVANCE VELOCITY AWARE PROBABILISTIC ROUTE DISCOVERY SCHEME (AVAP)

The efficiency of SVAP scheme can be improved if a proper timer and probabilistic function are considered to differentiate between the RNs and U-RNs. It is clearly noticed that SVAP scheme uses a fixed random timer for all different nodes regardless of their reliability. This may cause a *simultaneous broadcast* problem as the timer for some nodes could expire at the same time. Hence, many nodes will rebroadcast simultaneously, which results in increasing the possibility of the number of the dropped RREQ packets. On the other hand, two fixed counters comparisons are used to set the rebroadcast probability. This enables RNs or U-RNs to have the same value of P. This increases the contention rate and leads to a huge competition while accessing the same shared wireless medium. Therefore, the need of improving the SVAP scheme can approximately eliminate the broadcast storm problem and keep the most reliable routes. For example, in Figure 1 node number 1 (i.e. RN) should have a high possibility to rebroadcast before node number 2 (i.e. U-RN) that have a low reliable link connect it to the source. Thus, a proper timer and counter threshold should be considered in SVAP scheme to differentiate between the RNs and U-RNs.

Motivated by the above shortcomings of SVAP scheme, we propose here a new version of SVAP namely *Advance Mobility Aware Probabilistic Based-Broadcast Scheme* (AVAP). A brief outline of the AVAP is given in Figure 5, and it operates as follows.

- When the Source (S) node sends a RREQ packet to find a destination, it adds its own velocity vector to the RREQ packet header.
- Once any Receiver (R) within the source transmission range receives the RREQ packet, it calculates the cosine angle θ , and then takes the rebroadcast decision:
    - The receiver is considered as U-RN if the value of $\theta > \theta_{Th}$. Then, a long $TIMER_{LONG}$ is initiated with a high counter threshold, C_{HIGH}. Steps (6-13).
    - A low rebroadcast Probability P_{LOW} is set to the U-RN, as a ratio between the P_i and the value of total C_{HIGH} as follows: $P_{LOW}= (Pi/C_{HIGH})$. Step (14).
    - Otherwise, the receiver is considered as RN, and initiates a short timer $TIMER_{SHORT}$ and a low Counter threshold C_{LOW}, Steps **(15-22)**.
    - A high rebroadcast probability P_{HIGH} is set to the RN as a ratio between the P_i and the value of the total C_{LOW} as follows: $P_{HIGH}=(Pi/C_{LOW})$. Step (23).
- Finally, the algorithm generates a Random Number (R_N) between (0, 1), then a node rebroadcasts the RREQ packet if R_N is less than the pre-assigned p. Otherwise the packet is simply dropped. Steps (24-28).

AVAP: **Advance Velocity Aware Probabilistic Scheme**

```
IF (RREQ PACKET RECEIVED FOR THE FIRST TIME = TRUE)
1:Ss ←GET_SOURCE_SPEED ()
2:Rs← GET_RECEIVER_SPEED ()
3:Pi→SET_INITIAL_PROBABILITY(0.7)
4:IF ( θ > θ Th) = TRUE {
5: Rs→SET_UNRELIABLE _NODE()
6: TIMERLONG→ SET _LONG_TIMER()
9:WHILE (TIMERLONG != EXPEIRED){
10: IF (THE SAME RREQ PACKET RECEIVED) = TRUE{
11:GET_NUMBER _COPY() {C=C+1}
12:END_IF
13:   END_WHILE
14: P→SET_REBROADCAST_PROBABILITY(){PLOW = Pi/CHIGH}
15:   ELSE IF ( θ < θ Th) = TRUE {
16: Rs→SET_RELIABLE _NODE()
17: TIMERSHORT→ SET _SHORT_TIMER()
18:WHILE (TIMERSHORT != EXPEIRED){
19: IF (THE SAME RREQ PACKET RECEIVED) = TRUE{
20:GET_NUMBER _COPY() {C=C+1}
21:END_IF
22:   END_WHILE
23: P→SET_REBROADCAST_PROBABILITY(){PHIGH = Pi/CLOW}
24: RN←RANDOMNUMBER(0,1)
25: IF RN<P = TRUE
26: REBROADCAST_RREQ()
27: ELSE
28: DROP_RREQ()
29: END_IF
```

Figure 5: Description of AVAP scheme.

4. PERFORMANCE ANALYSIS

The performance and capabilities of the proposed broadcast schemes are examined and investigated using NS-2.34 as the simulation platform [8]. For each data points in all the figures, at least 30 experiments are used, each one represents different network topology with 95% confidence intervals. The number of nodes in the network was chosen between 20 to 200 nodes for all scenarios. The nodes are placed in 1000m X 1000m square area. The random waypoint model [9] is used as the mobility model. In this model, mobile nodes move freely and randomly without boundary restrictions. The application layer at each node generates CBR traffic. Maximum nodes speed varies between 5m/s to 100m/s. Due to its high capability in MANETs, AODV routing has been adopted in our experiments. SVAP, AVAP, Blind Flooding (BF), FB and FC have been examined within the underlying AODV routing protocol. In our experiments, we refer to our proposed scheme as SVAP-AODV, AVAP-AODV and we investigate its performance, in comparison with BF-AODV, FB-AODV and FC-AODV that we have discussed in Sections 3.

- **Performance Metrics**

In this study we evaluate the broadcast schemes using the following performance metrics:

- ***Routing Overhead:*** it represents the total number of RREQ packets that each node generates and rebroadcasts during the period of the simulation time.
- ***Links stability:*** It refers to the number of route breakage numbers.

4.1 EFFECT OF NETWORK MOBILITY

This section investigates the effect of network mobility on the proposed schemes. we collect the results of the performance comparisons, when the nodes max speeds are 5m/s, 20m/s, 40m/s, 80m/s, 100m/s respectively.

- **Routing Overhead**

Figure 6 shows the routing overhead of AVAP-AODV, SVAP-AODV, FP-AODV, FC-AODV and SVAP-AODV with different nodes speeds, when the number of CBR is set at 10. When the node speed increases, the stability of the existed route of the source and destination is decreased. This can increase the number of invalid routes between nodes. In such circumstances, more RREQ packets are generated and retransmitted in order to re-establish the announced invalid routes. It is clearly noticeable in Figure 6 how AVAP-AODV keeps the network stable with less possible number of RREQ packets. For instance, the AVAP-AODV performs better than FP-AODV and FC-AODV as the routing overhead is reduced approximately around 70%, 45% and 30% compared to BF-AODV.

- **Links Stability**

To measure the links stability we calculate the number of broken links, which occurred during the total simulation time in each scheme. The RERR packet is generated when any node that is a part of the route has invalid link to its neighbours. In this study such a node is called U-RN and it is responsible for sending RERR packet to inform the source that the current route is broken and a new route discovery session is required. Apparently, the new proposed schemes successfully eliminate the number of U-RNs, and, thus, the number of broken links is reduced as shown in Figure 7.

4.2 EFFECT OF NETWORK DENSITY

In these simulation experiments, we evaluate the performance of the proposed schemes under different network density, which can vary from low, medium to high. To mimic the three scenarios of density, we deploy 20 nodes, 40 nodes up to 200 nodes over 1000m X 1000m square area. Each node has a random maximum speed of 20m/s.

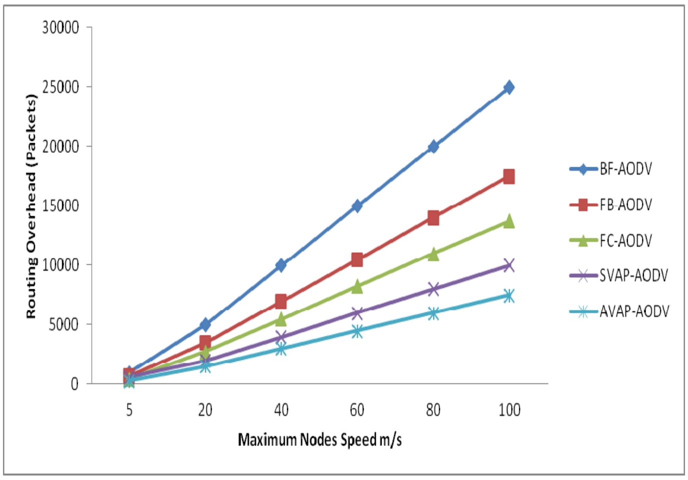

Figure 6: Routing Overhead vs. Maximum nodes speed

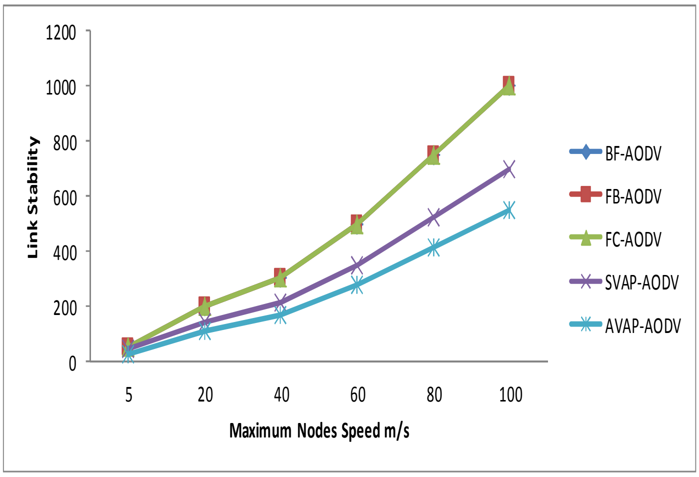

Figure 7: link Stability vs. Maximum nodes speed.

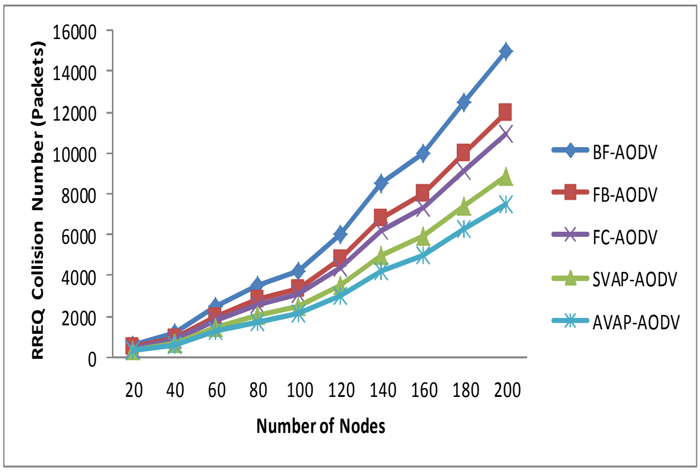

Figure 8: Routing Overhead vs. Number nodes.

- **Routing Overhead**

Figure 8 illustrates the routing overhead incurred by our proposed scheme in comparison with that exhibited by the other schemes. Figure 8 shows that as the number of nodes increase the number of RREQ packets increases proportionally. This is a normal behaviour for the all proposed schemes, since the number of the forwarded nodes increases by increasing the number of nodes. However, SVAP-AODV and SVAP-AODV achieves the best performance.

- **Links Stability**

Figure 9 shows the links stability in terms of the number of broken links within different network density. According to the results plotted in Figure 9, as the number of nodes increases the number of broken links decreases. This is because the network trends to be stable in a congested area, which forces the nodes to decrease their speed. This is can be noticed in a real life scenario such as vehicles movement on roads. For example during rush hours vehicles move slowly due to the traffic congestion phenomenon. SVAP-AODV and AVAP-AODV schemes ensure the best performance among all the other traditional schemes.

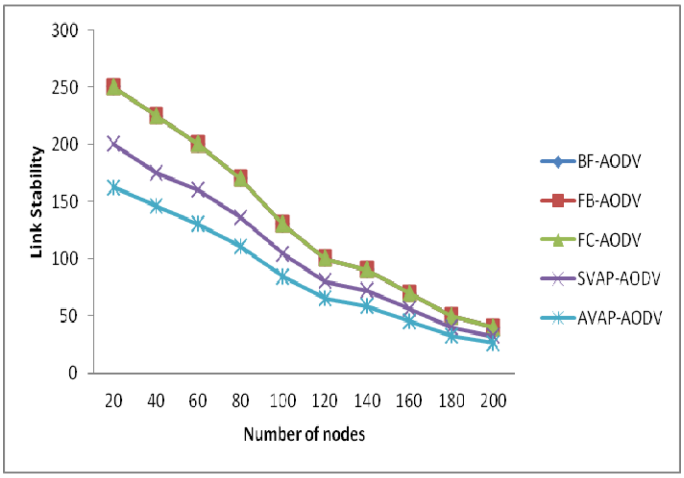

Figure 9: link stability vs. Number of nodes.

5. Conclusion and Future work

In this study, we propose a new probabilistic broadcast strategy for MANETs, which overcomes the limitation of existing broadcasting schemes. It is shown through extensive simulations that the new proposed schemes outperform BF-AODV, FP-AODV and FC-AODV schemes in different operating conditions. Unlike the pervious works, our strategy is based on the node velocity vector information to adaptively adjust the rebroadcast probability and categorize the reliability of the nodes accordingly. We applied this velocity vector within AODV and evaluated its performance in terms of different important metrics such as link stability and RREQ packet overhead. The main gain of our model is to avoid the route re-discovery phase by the traditional AODV especially at high mobility nodes. The SVAP-AODV scheme can be enhanced further by adding dynamic counter and timer concepts to the mobility aware probabilistic scheme. Therefore, we have extended the SVAP-AODV with AVAP-AODV to overcome the existing shortcomings. Our target in the future work is to develop an analytical model for the timer and probabilistic function based on velocity vector information between the sender and the receiver nodes.

REFERENCES

[1]C. Perkins and E. Royer, "Ad-hoc on-demand distance vector routing," *Second IEEE Workshop on Mobile Computing Systems and Applications (WMCSA)*, pp. 90 –100, Feb 1999.

[2]Y.-C. Tseng, S.-Y. Ni, Y.-S. Chen and J.-P. Sheu, "The broadcast storm problem in a mobile ad hoc network," *Wireless Networks*, vol. 8, pp. 153–167, 2002.

[3]S. Leu and R.-S. Chang, "Simple algorithm for solving broadcast storm in mobile ad hoc network," *IET Communications*, vol. 5, no. 16, pp. 2356 –2363, Nov 2011.

[4]M. Bani Yassein, M. Bani Khalaf, and A. Al-Dubai, "A new probabilistic broadcasting scheme for mobile ad hoc on-demand distance vector (aodv) routed networks," *The Journal of Supercomputing*, vol. 53, pp. 196–211, 2010.

[5]O. Tonguz, N. Wisitpongphan, J. Parikh, F. Bai, P. Mudalige, and V. Sadekar, "On the broadcast storm problem in ad hoc wireless networks," in *3rd International Conference on Broadband Communications Networks and Systems,* pp. 1 –11, 2006.

[6]P. Y. Taifei Zhao, Xizheng Ke, "Position and velocity aided routing protocol in mobile ad-hoc networks," *International Journal of Digital Content Technology and its application*, vol. 4, pp. 101–109, 2010.

[7]A. Mohammed, M. Ould-Khaoua, L. Mackenzie, and J.-D. Abdulai, "Dynamic probabilistic counter-based broadcasting in mobile ad hoc networks," *2nd International Conference on Adaptive Science Technology (ICAST)*, pp. 120 –127, Jan 2009.

[8]http://isi.edu/nsnam/ns/.

[9]W. Navidi and T. Camp, "Stationary distributions for the random waypoint mobility model," *IEEE Transactions on Mobile Computing,* vol. 3, no. 1, pp. 99 – 108, Jan-Feb 2004.