International Journal of Recent Trends in Engineering & Research
ISSN : 2455-1457 Impact Factor : 3.344

Review on Performance Analysis of Probabilistic Route Discovery for Wireless Mobile Ad hoc Networks

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Abstract— Mobile wireless ad hoc networks (MANETs) have become of increasing interest in view of their promise to extend connectivity beyond traditional fixed infrastructure networks. In MANETs, the task of routing is distributed among network nodes which act as both end points and routers in a wireless multi-hop network environment [2]. To discover a route to a specific destination node, existing on-demand routing protocols employ a broadcast scheme referred to as simple flooding whereby a route request packet (RREQ) originating from a source node is blindly disseminated to the rest of the network nodes. This can lead to excessive redundant retransmissions, causing high channel contention and packet collisions in the network, a phenomenon called a broadcast storm. To reduce the deleterious impact of flooding RREQ packets, without sacrificing performance gains through the use of probabilistic broadcast methods, where an intermediate node rebroadcasts RREQ packets based on some suitable forwarding probability[13] rather than in the traditional deterministic manner. In this study the the performance of the routing protocols Ad hoc On demand Distance Vector (AODV) and Dynamic Source Routing (DSR) augmented with probabilistic route discovery, taking into account parameters such as network density, network traffic and nodal mobility. The results reveal encouraging benefits in overall routing control overhead but also show that network operating conditions have a critical impact on the optimality of the forwarding probabilities.

Keywords— MANETs, AODV, DSR , Probabilistic Route Discovery, NS-2.

I. INTRODUCTION

In traditional on-demand routing protocols, e.g. AODV [1] and DSR [2], route request (RREQ) packets are disseminated throughout the entire network in search of a particular destination. In particular, each node forwards a received RREQ packet once until a destination is reached. This method of route discovery is known as simple flooding [5]. However, in on-demand routing protocols, once a route to a destination has been established, all the intermediate nodes along the route adhere to the forwarding responsibilities of data packets. Therefore some of the RREQ packet transmissions associated with a route discovery is redundant. As a consequence, the number of retransmissions of RREQ packets during the route discovery process can seriously affect the performance of the routing protocol in terms of communication overhead and end-to-end delay [3, 4].

To reduce the communication overhead associated with the dissemination of broadcast packets in “pure” broadcast scenarios while still maintaining an acceptable level of reach ability, probabilistic approaches have been proposed as an alternative to simple flooding [5, 6, 7, 12]. In the probabilistic schemes, upon receiving a broadcast packet for the first time, a node forwards the packet with a pre-determined forwarding probability p and drops the packet with the probability 1-p, as shown in Figure 1. Every forwarding node is assigned the same forwarding probability p and when p = 1 the probabilistic scheme reduces to simple flooding.

The effects of network density, traffic and node mobility on probabilistic flooding in a pure broadcast scenario have been analysed over a wide range of forwarding probabilities [7]. The main objective of this study is to conduct an extensive performance analysis by means of Ns-2 [9] simulations of probabilistic route discovery in two popular on-demand routing protocols, namely AODV [1] and DSR [2]. In the case of probabilistic route discovery, each received RREQ packet is forwarded once with the forwarding probability p (see Figure 1).

The performance analysis is conducted over a range of forwarding probabilities from 0.1 to 1 in steps of 0.1. The performance analysis is conducted using the most widely used performance metrics: throughput, delivery ratio, network connectivity, end-to-end delay, routing overhead and collision rate. The remainder of this study is organized as follows: the simulation model and the system parameters. To analyze the effects of network operating conditions on the performance of fixed probabilistic route discovery in both AODV and DSR. Finally, its conclusion.

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Algorithm: Fixed Probabilistic Route Discovery

Upon receiving a RREQ packet request at a node
if RREQ is received for the first time
set rebroadcast probability to p = po
        end if
Generate a random number Rnd over the range [0,1]
        if Rnd <= p
              broadcast the RREQ packet
              drop the packet
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Figure 1. An outline of the algorithmic for probabilistic route discovery

Simulation Model and System Parameters

The NS-2 simulation model consists of two sets of scenario files; topology scenario files and traffic generation pattern files. The topology scenario files define the simulation area and the mobility model of randomly distributed mobile nodes over the simulation time period. On the other hand, the traffic pattern files define the characteristics of data communications, notably, data packet size, packet type, packet transmission rate and the number of traffic flows. The propagation model used is the Ns-2 [9] default which combines both a free space propagation model and a two-ray ground reflection propagation model [11]. The simulation scenarios consist of three different settings, the impact of network density or size is assessed by varying the number of mobile nodes placed on an area of fixed size 1000m x 1000m. The second simulation scenario investigates the effects of node mobility on the performance of probabilistic route discovery by varying the maximum speed of a fixed number of mobile nodes placed on a fixed area of 1000m x 1000m. The last simulation scenario evaluates the performance impact of traffic offered load on the algorithms by providing a different number of traffic flows for a fixed number of nodes placed on a 1000m x 1000m topology area. Data packet with size 512 bytes and sending rate of 4 packets/sec have been used. The forwarding probabilities have been varied from 0.1 to 1.0, with 0.1 increments per simulation trial, and each data point for each forwarding probability represents an average of 30 randomly generated topology scenario files.

In this study, mobile nodes move according to the widely used random waypoint mobility model [8, 10], where each node at the beginning of the simulation remains stationary for pause time seconds, then chooses a random destination and starts moving towards it with a speed selected from a uniform distribution [0, max V]. After the node reaches its destination, it again stands still for a pause time interval t sec and picks up a new random destination and speed. Other simulation parameters used are summarized below in Table-1.

The statistics have been collected using a 95% confidence level over 30 randomly generated topologies which have been found to have the lowest relative error compared with the 20 and 25 topologies. The error bars in the graphs represent the upper and lower confidence limits from the means and in most cases they have been found to be quite small.

Simulation Parameter	Value
Simulator	NS-2 (v.2.29)
Transmitter range	250 meters
Bandwidth	2 Mbps
Interface queue length	50packets
Traffic type	CBR
Packet size	512 bytes
Simulation time	900 sec
Number of trials	30
Topology size	1000m x 1000m
Number of nodes	25, 50, 75, . . . , 225
Maximum speed	1m/sec 5m/s, 10m/sec, ... , 25m/s

Table 1. System parameters, mobility model and protocol standards used in the simulation experiments

II. PROPOSED WORK

It shows performance comparison analysis of the fixed probabilistic route discovery technique in both AODV [1] and DSR [2]. The current AODV and DSR, have been modified in order to implement the fixed probabilistic route discovery, such implementations are referred to as FP-AODV and FP-DSR. In each of the modified routing protocols, a route discovery process is initiated when the source node needs to send a data packet, but does not have a valid route to the destination, or when an active route to the destination is broken.

1. Effects of Traffic Load

This section demonstrates the effects of traffic load on the performance of FPAODV and FP-DSR for different forwarding probabilities. In this study, 150 nodes are placed over 1000m x 1000m and each node is moving according to the random way point mobility model with a maximum speed of 20m/s. To investigate the impact of traffic load, the numbers of source-destination connections (or flows) have been varied; 5 and 10 flows. The source destination pair for each of the connections is chosen at random and consists of a CBR flow from the source to destination.

Routing Overhead: The results in Figure 2 show the effects of offered traffic load on the performance of FP-AODV and FP-DSR in terms of routing overhead across different forwarding probabilities. Figure 12 shows that significant savings can be achieved by reducing the number of RREQ packets transmitted in highly congested networks when the forwarding probability is set low. However, if the number of retransmissions of RREQ packets is much lower than optimal, this may result in the route search dying out quite early, which will require another round of route discovery. Compared with FP-AODV, FP-DSR generates less routing overhead across all forwarding probabilities, especially when a large number of traffic flows is used. The savings achieved by FP-DSR in terms of routing overhead are due to the use of cached routes.

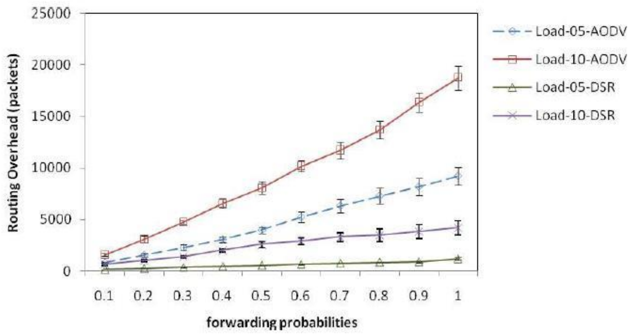

Figure 2. Routing overhead vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m area when offered traffics of 5 and 10 flows are used.

Collision Rate: Figure 3 depicts the performance of the two routing protocols in terms of collision rate for different forwarding probabilities when offered loads of 5 and 10 flows are used. The figure reveals that for a given number of offered loads, the collision rate increases almost linearly with increased forwarding probability. The results in the figure also demonstrate that for a given forwarding probability, the collision rate in each of the routing protocols increases with increased offered load. This is because of the increase in the congestion levels when the number of source destination pairs in the network is increased. Figure 3 also reveals that, across all the forwarding probabilities, the FP-DSR protocol incurs a lower collision rate when compared with FP-AODV for both 5 and 10 flows.

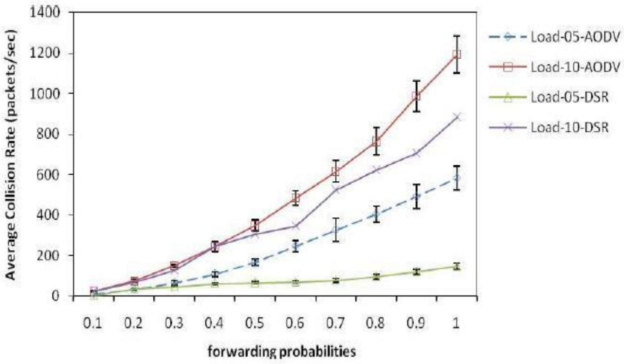

Figure 3. Average collision rate vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m area when offered traffics of 5 and 10 flows are used.

Connectivity Success Ratio: Figure 4 plots the performance properties of FP-AODV and FP-DSR in terms of the network connectivity success ratio against forwarding probabilities. The figure reveals that the network connectivity in FP-AODV is low when the forwarding probability is set low (e.g. $p < 0.4$) and when it is set high (e.g. $p > 0.8$). This is due to the fact at low probabilities fewer than optimal number of RREQ packets are transmitted in FP-AODV. On the hand when the probability is set high, more redundant transmission of RREQ packets induce a larger number of packet collisions causing some of the RREQ packets to fail to reach their respective destinations. In FP-DSR, the performance is slightly affected by the varying forwarding probabilities when the offered load is relatively small (e.g. 5 flows). However, at relatively large offered load (e.g. 10 flows), the connectivity dropped sharply with increased forwarding probability. Furthermore, the figure shows that, for a given offered load, the FP-DSR has a clear performance advantage over FP-AODV when the offered load is low and the forwarding probability is set low.

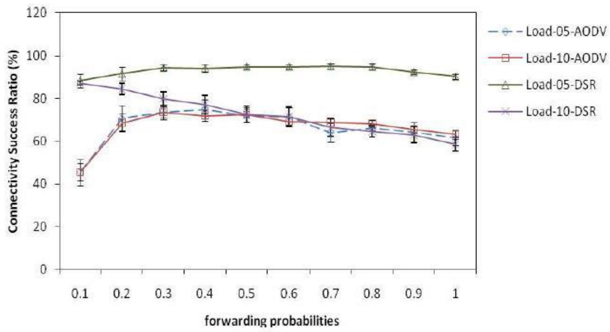

Figure 4. Network connectivity vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m area and offered traffic of 5 and 10 flows are used.

Normalised Throughput: In Figure 5, the performance properties of FP-AODV and FP-DSR in terms of network throughput for offered loads of 5 and 10 flows is plotted against the forwarding probability. The Figure 5 reveals that the normalised throughput of FP-AODV increases to a maximum of about 0.80 and 0.76 for 5 and 10 flows respectively when the forwarding probability is increased from 0.1 to 0.7, and dropp ed to around 0.71 and 0.66 for 5 and 10 flows respectively when forwarding probability is increased from 0.7 to 1. However in FP-DSR, the normalised network throughput degrades sharply with increased forwarding probability when 10 flows is used and remains slightly affected when 5 flows is used.

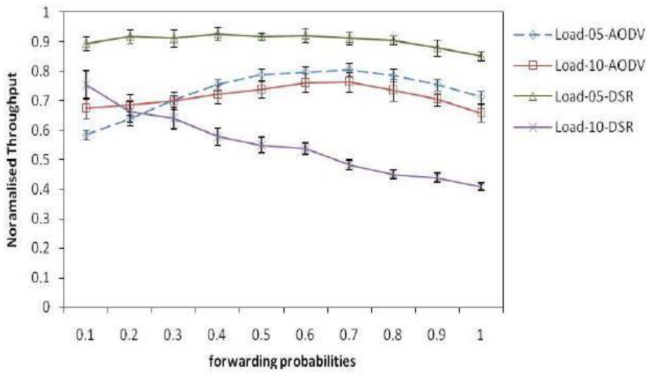

Figure 5. Network throughput vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m area and offered traffic of 5 and 10 flows are used.

End-to-End Delay: Figure 6 presents the end-to-end delay of the two routing protocols versus the forwarding probability for different offered loads. Increasing the number of flows results in an increase in the number of nodes contending for channel and the probability of packet collisions. These phenomena can potentially increase the time elapsed to discover routes, as a consequence the end-to-end delay of the data packets is increased. For example, in Figure 6 the end-to-end delay incurred by FP-AODV and FP-DSR at forwarding probability p = 1 is increased by around 30% and 270% respectively when the offered load is increased from 5 to 10 flows. The results in Figures 6 also show that FP-DSR incurs a much longer delay than FP-AODV for a large number of flows and high forwarding probability. This is due to the high number of stale routes and packet collisions associated with FP-DSR, especially in congested networks.

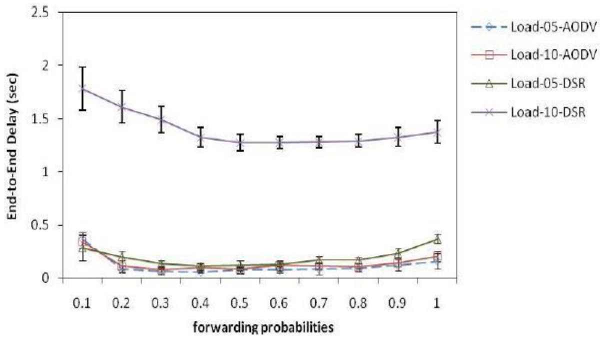

Figure 6. End-to-end delay vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m moving at a maximum speed of 5m/sec when traffic flows of 5 and 10 are used.

2. Effects of Network Density

The performance impact of network density on FP-AODV and FP-DSR over different forwarding probabilities. The network density has been varied by deploying 100 and 150 nodes over a fixed area of 1000m x 1000m for different forwarding probabilities. Each node in the network moves with a speed randomly chosen between 0 and 20m/sec. 10 identical random source destination connections (i.e. traffic flows), each generating 4 data packets per second, have been used. The packet size is 512 bytes. In the figures presented below, the x-axis represents the variations of forwarding probabilities, while the y-axis represents the results of the performance metric of interest.

Collision Rate: Figure 7 shows the effects of network density on the performance of FP-AODV and FP-DSR in terms of average collision rate. The collision rate for a given network size (i.e. a given number of nodes) decreases almost linearly with decreasing forwarding probabilities. This is due to the fact that decreasing the forwarding probability reduces the chances of two or more nodes in the same transmission range transmitting at the same time, leading to a possible reduction in the number of collisions. For example in Figure 7, when the forwarding probability is reduced from p = 1 (i.e. simple flooding) to p = 0.7, the collision rate in FP-AODV for both the 100 and 150 node networks is reduced by approximately 88% and 93% respectively, while in FP-DSR the collision rate is reduced by as much as 119% for a 100 node network and approximately 70% for a 150 node network.

Routing Overhead: Figure 8 shows the routing overhead incurred by FP-AODV and FP-DSR versus forwarding probabilities for different network densities. The routing overhead in this study represents the number of RREQ packets generated and disseminated throughout the network. The figure reveals that for a given network density, the routing overhead incurred by each of the routing protocols decreases almost linearly as the forwarding probability decreases. For example, when the probability is reduced from

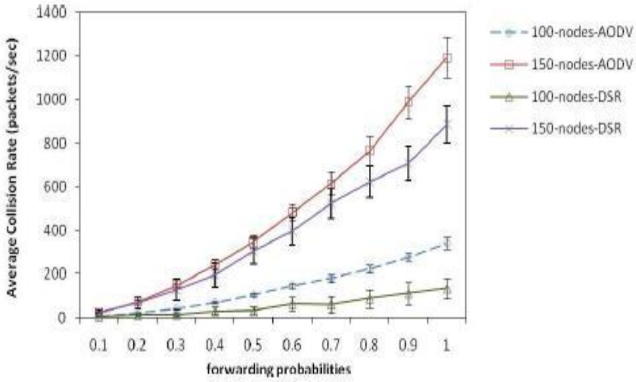

Figure 7. Average Collisions rate vs. forwarding probabilities for 100-node and 150-node networks

p = 1 to p = 0.7 , the routing overhead in FP-AODV is reduced by approximately 54% for the 100 nodes network and 60% for the 150 nodes network. For a similar reduction of the forwarding probability in FP-DSR, the routing overhead is slightly reduced by approximately 7% in the 100 nodes network and about 27% in the 150 nodes network. This is because when the forwarding probability is decreased, the number of redundant retransmissions of RREQ packets is reduced; redundant retransmission occurs when an intermediate node forwards an RREQ packet that has been received by all its immediate neighbours.

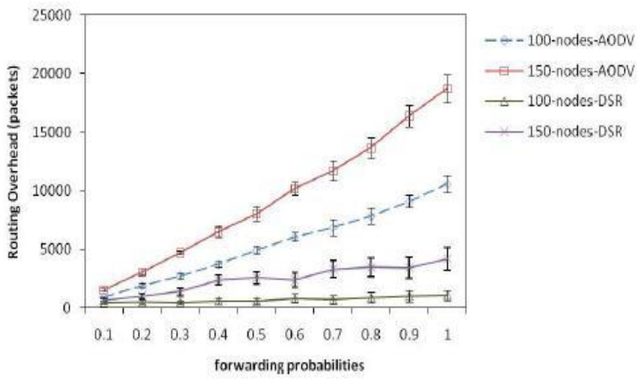

Figure 8. Routing overhead vs. forwarding probabilities for 100-node and 150-node network

Connectivity Success Ratio: Connectivity Success ratio measures the percentage of route discovery processes that succeed in finding a route. In a moderate to large sized networks, broadcast redundancy contributes to excessive network congestion which increases the chances of packet collisions and contention for the communication channel, and as a consequence, the connectivity success ratio of the network is reduced. As seen in Figure 9, the connectivity success ratio of FP-AODV is relatively low for both high and low forwarding probabilities (e.g. p < 4 and p > 7) respectively. For p < 4, fewer than optimal number of nodes is allowed to forward the RREQ packets, thereby preventing some of the RREQ packets from reaching their destinations. On the hand, for p > 7, more than optimal number of nodes in the network are allowed to forward the RREQ packets, as a consequence, the channel contention and packet collisions are increased thereby reducing the capacity of the available bandwidth for the data communication. The connectivity success ratio in FP-DSR drops sharply in relatively dense network (e.g. 150 nodes). This is due to the path accumulation on the RREQ packets which increases the size of the packets. As a consequence, the probability of packet collision in the network is increased.

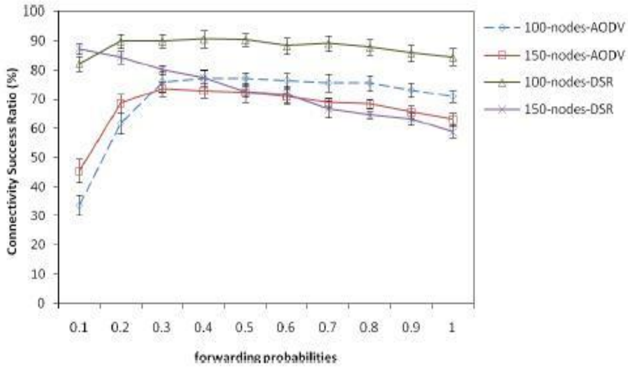

Figure 9. Network connectivity vs. forwarding probabilities for 100-node and 150-node networks

Normalised Network Throughput: In Figure 10, the normalised network throughput of FP-AODV and FP-DSR is plotted against forwarding probabilities for different network sizes of 100 and 150 nodes placed in a topology area of 1000m x 1000m. The results shows that for FP-AODV, the normalised aggregate throughput in both topology scenarios (i.e. 100 and 150 nodes networks) increases as the forwarding probability increases from 0.1 to 0.6. On the other hand, the throughput decreases as the forwarding probability increases from 0.7 to 1.0. The normalised throughput in FP-DSR for each of the network densities decreases as the forwarding probability increases from 0.1 to 1. The results also show that at low forwarding probability normalized throughput of FP-AODV is relatively lower compared with that of FP-DSR. However, in a dense network the FP-AODV outperforms the FP-DSR when the forwarding probability is set high, particularly in a dense network.

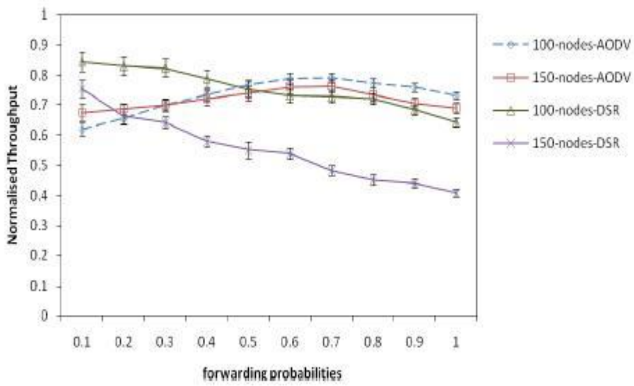

Figure 10. Throughput vs. forwarding probabilities for 100-node and 150-node networks

End-to-End Delay: In Figure 11, the results of FP-AODV and FP-DSR in terms of the average end-to-end packet delay are plotted against forwarding probabilities. Figure shows that the delay incurred by each of the two protocols is longer for both low and high forwarding probabilities. The results also show that the FP-DSR incurs higher delay compared with the FP-AODV. This is due to the fact that the FP-DSR often relies on cached routes for data transmission.

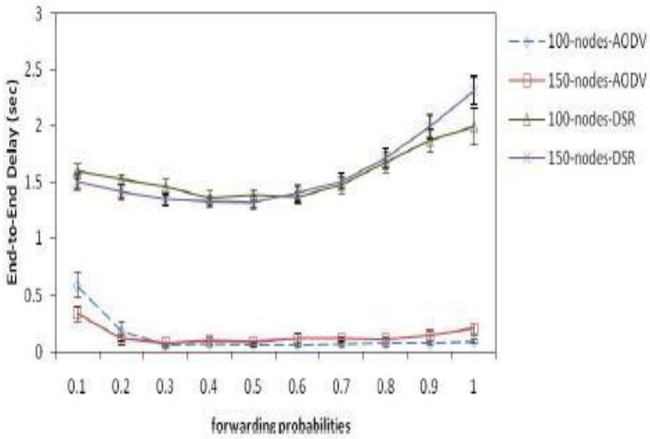

Figure 11. End-to-end delay vs. forwarding probabilities for 100-node and 150-node networks

3. Effects of Node Mobility

This section shows the effects of node mobility on the performance of FP-AODV and FP-DSR. In this study, 150 nodes are placed over 1000m x 1000m with each node moving according to the random waypoint mobility model with a maximum node speed of maxV . The node mobility is varied by changing the value of maxV . For each simulation scenario, 10 identical randomly selected source destination connections are used.

Routing Overhead: In Figure 12 the impact of node mobility on the performance of FP-AODV and FP-DSR in terms of the routing overhead is plotted against the forwarding probability. In particular, the figure demonstrates that across all forwarding probabilities, the routing overhead incurred by FP-AODV and FP-DSR increases with increased node mobility. This is due to the fact that an increase in node mobility results in an increase in the number of broken links and the failure of some route request packets to reach their destinations. The results in the figure also reveal that for a given maximum node speed, the routing overhead in each of the protocols decreases as the forwarding probability decreases. This is because in moderate to high density networks 150 nodes), which guarantee relatively full network connectivity, the number of redundant retransmissions of RREQ packets increases when the forwarding probability increases. However, across all forwarding probabilities, FP-DSR outperforms FP-AODV by reducing the routing overhead for both 5m/sec and 10m/sec. The superior performance of FP-DSR is due to its aggressive use of cached routes.

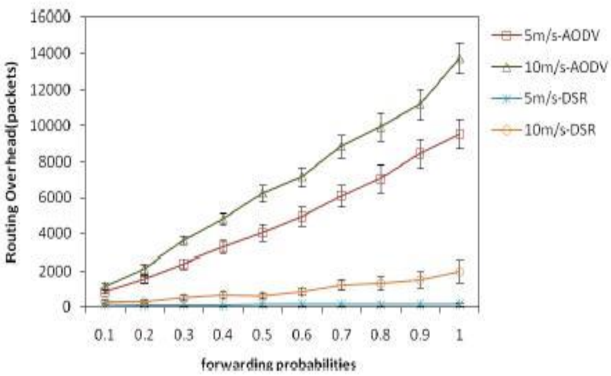

Figure 12. Routing overhead vs. forwarding probabilities of 150 nodes placed over a 1000m x 1000m area moving with different maximum speeds

Collision Rate: In Figure 13, the results of the two routing protocols in terms of average collision rate for different maximum node speeds are plotted against the forwarding probabilities. Overall, across different forwarding probabilities, the collision rate in each of the two routing protocols increases with increased node mobility. For example, in Figure 13, the collision rate at p = 1 is increased by approximately 64% and 500% in FP-AODV and FP-DSR respectively when the speed is increased from 5m/s to 10m/s. This is due to the increased number of broken routes as node mobility increases which require more route discovery operations to be initiated for new routes. As a consequence, the congestion levels and the number of collisions in the network are increased.

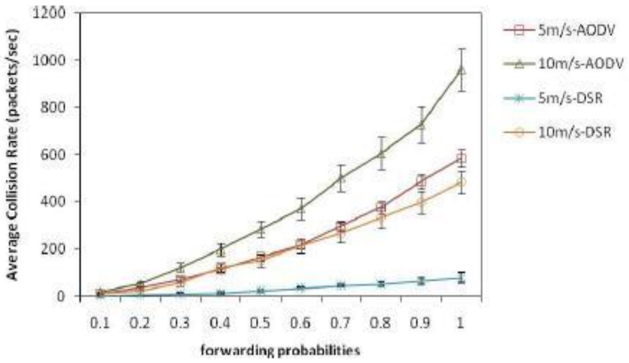

Figure 13. Collision rate vs. forwarding probabilities of 150 nodes deployed over 1000m x 1000m area moving with different maximum speeds

Connectivity Success Ratio: For FP-AODV, the connectivity success ratio of both speeds first increases as the forwarding probability increases. They start to decrease after reaching a maximum when the forwarding probability is increased. The figure also show that across forwarding probabilities, the connectivity success ratio of FP-AODV decreases as the speed increases. This is due to the increased in the number of broken routes when the mobility is increased. In FP-DSR, connectivity success ratio first increases when the probability is increased until around p = 0.6 , when the maximum speed in the network is 5m/s. However, when a relatively high speed is used (e.g. 10m/s), the connectivity of FP-DSR starts to drop after p = 0.2 . The figure also reveals that, at relatively low forwarding probability, the FP-DSR with relatively fast moving nodes has a higher connectivity than the FP-DSR with slow moving nodes. On the other hand, the connectivity of FP-DSR with fast moving nodes is lower compared with the FP-DSR with slow moving nodes when the forwarding probability is increased. For a given routing protocol, the connectivity decreases as the speed increases when the forwarding probability is set high (e.g. probabilities greater 0.4). The results in Figure 14 also reveal that FP-DSR outperforms FP-AODV in both mobility cases across all forwarding probabilities.

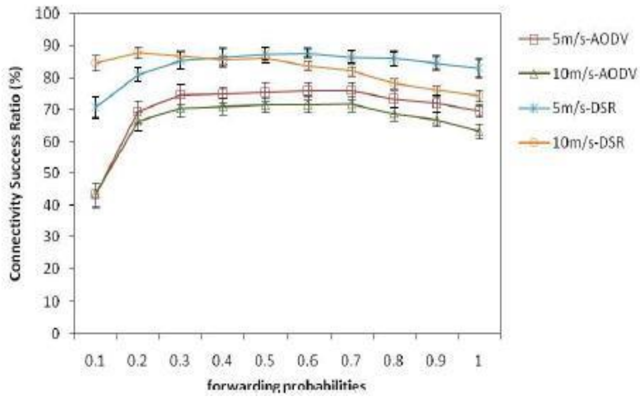

Figure 14. Network connectivity vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m area moving with different maximum speeds

Normalised Network Throughput: Figure 15 depicts the normalised throughput in both FP-AODV and FP-DSR versus the forwarding probability for different maximum speed. It shows that for 5m/s and 10m/s, the normalised throughput of FP-AODV increases to a maximum of 96% and 73% respectively when the forwarding probability is increased from 0.1 to 0.7, and dropped to approximately 92% and 64% respectively when the forwarding probability is increased. On the other hand, for a maximum node speed of 10m/s, the throughput in FP-DSR degrades sharply from 89% to 65% when the forwarding probability is increased from 0.1 to 1. At relatively low speed (e.g. 5m/s), the normalised throughput in FP-DSR is slightly affected. Although FP-DSR has a higher connectivity success ratio than FP-AODV for 10m/s as shown in Figure 14, the normalised throughput is lower than FP-AODV. This is because some of the routes used for the data transmission in FP-DSR are stale.

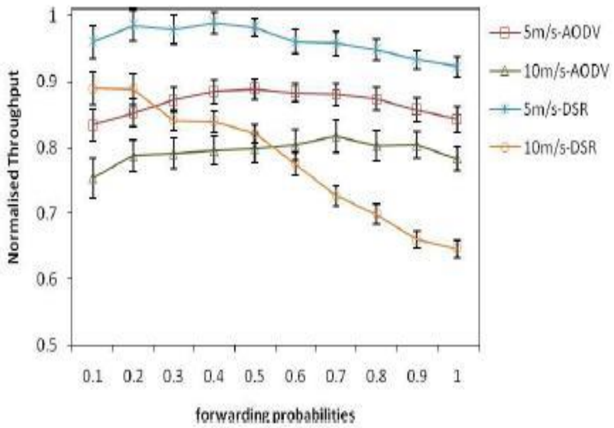

Figure 15. Throughput vs. forwarding probabilities of 150 nodes placed over a 1000m x 1000m area moving with different maximum speeds

End-to-End Delay: The end-to-end delay of FP-AODV and FP-DSR for different speeds is reported in Figure 16. The figure shows that at a given maximum speed, the end-to-end delay incurred by each of the routing protocols is longer when the forwarding probability is set low. This is because at low forwarding probabilities, fewer than the optimal number of nodes forwards the RREQ packets; as a consequence, some of the initiated RREQ packets fail to reach their destinations. The figure also shows that the performance of FP-DSR in relatively high mobility scenarios is worse when compared with FP-AODV. The worse performance of FP-DSR is due to the use of stale routes for data transmission and the time used to transmit large control packets (e.g. RREQ packets) during route discovery.

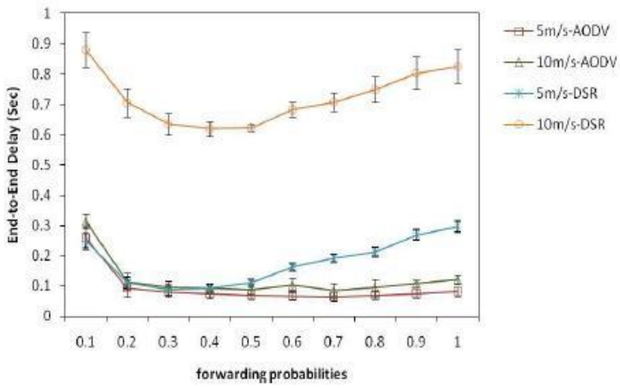

Figure 16. End-to-end delay vs. forwarding probabilities of 150 nodes placed over 1000m x 1000m area moving with different maximum speeds

III. CONCLUSIONS

This study shows performance analysis of two on-demand routing protocols that are based on probabilistic route discovery, namely FP-AODV and FP-DSR, in order to assess their behavior in various network operating environments. The first part of the study shows the effects of different network densities in terms of deploying different numbers of nodes over a fixed size topology area. The forwarding probability has been varied from 0.1 to 1 in steps of 0.1. The second part of the study shows the effects of node mobility on the performance of probabilistic route discovery in FP-AODV and FP-DSR by varying the maximum node speed. The results presents for a given network setup with a given network density and node mobility, considerable savings can be achieved in terms of RREQ packet dissemination and collisions without degrading the overall network performance in terms of network throughput and end-to-end packet delay, provided that an appropriate forwarding probability is selected. For example, the results have revealed that using a optimal forwarding probability in a moderate to large sized network can reduce routing overhead as well as the rate of collisions while still achieving a good performance level in terms of throughput and delay.

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