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An Analysis of Probabilistic Route Discovery Mechanism based on node mobility

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*Abstract— **an ad hoc wireless network consists of set of mobile nodes connected without any central administration. Path finding processes in on-demand route discovery methods in mobile ad hoc networks (MANETs) use flooding. Source mobile node simply broadcast route request (RREQ) packet to its neighbour node and once again the neighbour node rebroadcast RREQ packet to its neighbour until unless route to a particular destination is found. The excessive RREQ packet can lead collision problem and consume more bandwidth in the network and decrease network performance [19]. This paper examined the fixed probabilistic (FP) based broadcast method using existing on demand routing protocols such as on demand distance vector routing protocols (AODV) and dynamic source routing protocol (DSR). The author used NS-2 simulator for the evaluation of FP-AODV and FP-DSR with traditional AODV[1] and DSR[2] routing protocols using various parameters such as collision rate, routing overhead, network connectivity and throughput. The simulation result shows significant improvement in FP-AODV and FP-DSR.***

Keywords: **MANET, AODV, DSR, RREQ, broadcast.**

I. INTRODUCTION

Ad hoc wireless network utilize multi-hop nature and operating without the support of any fixed infrastructure. Hence this type of network called infrastructure less network. The absence of any central coordinator the routing protocol makes routing is very difficult. The path setup between two nodes is completed by the help of intermediate node. The routing is responsibilities of routing protocol, which include exchanging the route information, finding good path to a destination based on good routing metrics such as hop length, minimum power and life time of the links; collecting information about the path breaks; restoration of broken path with short processing power and bandwidth; and utilizing minimum bandwidth. The routing protocols faces many challenges such as mobility, bandwidth constraints, error-prone and shared channel, location dependent contention etc,. The major needed of routing protocol in ad hoc wireless networks are minimum route acquisition, quick route reconfiguration, loop free routing, distributed routing approach, minimum control overhead, scalability, quality of service, time sensitive traffic, security and privacy. The major challenge in MANET is multi-hop behavior. For Ad hoc network several routing protocols have been proposed. These protocols classified into three categories such as proactive or table driven routing protocols, reactive or on demand routing protocols and hybrid routing protocols. The table –driven routing protocols, all node keep the network topology information in the form of routing tables by periodically exchanging information. Routing information is flooded in whole network. If node require route to destination, it runs path finding algorithm to find the route. For example destination sequenced distance vector routing protocols (DSDV), Wireless routing protocols (WRP), Cluster Head Gateway Switch routing protocols (CGSR) are working under proactive routing. Reactive routing protocols do not maintain topology information, whenever the source node required route it initiates path finding process. These protocols do not exchange routing information periodically. For example Ad hoc on demand distance vector routing protocol (AODV),Temporally ordered routing algorithm (TORA),Location aided routing (LAR) and dynamic source routing protocols (DSR) are coming under reactive protocols. Hybrid routing protocols has the best features of proactive and reactive routing protocols. For example zone routing protocols (ZRP), Core extraction distributed ad hoc routing protocols (CEDAR) coming under hybrid category.

In on demand distance vector routing protocol, the source node initiates RREQ packet and broadcast to its neighbors. The broadcasting is referred as flooding. For example the source S may initiate a destination search using RREQ packet. This packet contains location of S, destination ID and some control bits. If destination not reaches the intermediate node receives RREQ packet and rebroadcast to its entire neighbor until the destination found. The blind flooding causes unnecessary collision and bandwidth waste. For this problem some optimization techniques applied. The flooding can be classified into simple or blind flooding, probability based flooding, area based flooding and neighbor knowledge methods. The neighbor knowledge based flooding further classified into clustering based flooding, selecting forwarding neighbors and internal node based flooding.

A straightforward flooding is very costly and will result serious redundancy, contention and collision. They identified this broadcast storm problem. Recently, probabilistic broadcast schemes for MANETs have been suggested for broadcast storm problem [3] associated with the simple flooding. In the probabilistic scheme, each node rebroadcast received RREQ packet with given fixed probability p. This method reduces the routing overhead.

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This paper introduce 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. In this paper section 2 shows related work, section 3 shows Analysis of Fixed Probabilistic Route Discovery; section 4 shows performance Analysis of Fixed Probabilistic Route Discovery and section 5 conclusions about this paper and future direction.

II. RELATED WORK

Broadcasting in MANETs is means one node sends a packet to all other nodes in a network. Simple flooding is the simplest form of broadcasting where the source node broadcasts a packet to its neighbouring nodes. Each neighbouring node receiving the broadcast packet for the first time rebroadcasts to its neighboring nodes. Finally, the broadcast propagates outwards from the source node, eventually terminating when every node has received and transmitted the broadcast packet exactly once.

Simple flooding broadcast mechanism ensures the full coverage of the entire network. The broadcast packet is guaranteed to be delivered to every node in the network, provided the network is static and connected. In large sized dense networks, simple flooding may gain far more transmissions than necessary for the broadcast packet to reach every node. Figure 2.1 shows a sample network with 5 nodes. When node v broadcasts a packet, nodes u, w and x receive the packet. u, w and x then forward the packet and lastly y also broadcasts the packet. The figure shows that there is a great deal of broadcast redundancy as a result of simple flooding in this case. Transmitting the broadcast packet only by nodes v and u is enough for the broadcast operation. If the size of the network (i.e. number of nodes) increases and the network becomes denser, more transmission redundancy will be introduced. This type of simple flooding will be initiated transmission collision and contention; this will affect the network performance. This phenomenon of broadcasting induces what is often referred to in the literature as the broadcast storm problem [3].

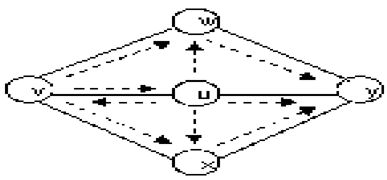

Fig 1. Example of a MANET of five nodes with redundant transmissions.

The broadcast storm problem can be avoided by reducing the number of nodes that forward the broadcast packet. Ni et al. [3] have classified several proposed broadcast algorithms in two categories: probabilistic and deterministic. William and Camp [4] have compared the performance of several proposed broadcast approaches including the probabilistic, counter-based, area- based, neighbour-designated and cluster-based. The following sections provide a brief description of each these approaches.

A. COUNTER-BASED METHODS

In this technique, when a node receives a broadcast packet, it starts a random assessment delay (RAD) and counts the number of received duplicate packets. When the RAD expires, the node rebroadcasts the packet only if the counter does not exceed a threshold value C. If the counter exceeds the threshold after expiration of RAD, the node assumes all its neighbours have received the same packet, and refrains from forwarding the packet. The predefined counter threshold C is the key parameter in this technique. Ni et al. [3] have demonstrated that broadcast redundancy associated with simple flooding can be reduced while maintaining comparable reachability in a network of 100 nodes, each with 500m transmission range placed on an area between 1500m x 1500m and 5500m x 5500m by using a counter based scheme with the value of C set to 3 or 4.

B. AREA BASED METHOD

A node using an Area Based Method can evaluate additional coverage area based on all received redundant transmissions. We note that area based methods only consider the coverage area of a transmission; they don't consider whether nodes exist within that area. The additional coverage area is determined by a distance-based scheme or location-based scheme. For example, if the node receiving the packet is located a few meters away from the sender, the additional area covered by forwarding the packet is quite low [3]. At the other extreme, if the node receiving the packet is located at the boundary of the sender's transmission range, then a rebroadcast would reach a significant additional area, 61%, as suggested in [5].

1) DISTANCE-BASED SCHEME:

A node compares the distance between itself and each neighbouring node that has previously forwarded a given packet. Upon reception of a previously unseen packet, a random assessment delay (or RAD for short) is initiated and redundant packets are cached. When the RAD expires, the locations of all the sender nodes are examined to see if any node is closer than a threshold distance value. If true, the node does not rebroadcast. Therefore, a node using the distance-based scheme requires the knowledge of the geographic locations of its neighbours in order to make a rebroadcast decision. A physical layer parameter such as the signal strength at a node can be used to gauge the distance to the source of a received packet. Alternatively, if a GPS receiver is available, nodes could include their location information in each packet transmitted. The distance-based scheme succeeds in reaching a large part of the network but does not economize the number of broadcast packets. This is because a node may have received a broadcast packet many times, but will still rebroadcast the packet if none of the transmission distances are below a given distance threshold.

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2) LOCATION-BASED SCHEME:

Using a location based scheme [3], each node is expected to know its own position relative to the position of the sender using a geolocation technique such as GPS. Whenever a node originates or forwards a broadcast packet it adds its own location to the header of the packet. When a neighboring node initially receives the packet, it notes the location of the sender and calculates the additional coverage area obtainable if it were to rebroadcast. If the additional area is less than a threshold value, the node will not rebroadcast, and all future receptions of the same packet will be ignored. Otherwise, the node assigns a RAD before delivery. If the node receives a redundant packet during the RAD, it recalculates the additional coverage area and compares that value to the threshold. The comparison of the area calculation and threshold occurs for all redundant broadcasts received until the packet reaches either the scheduled send time or is dropped.

C. NEIGHBOUR KNOWLEDGE BASED METHODS

Neighbour knowledge based schemes [6, 23] maintain state information about their neighborhood via periodic exchange of "hello" packets, which is used in the decision to rebroadcast. The objective is to predetermine a small subset of nodes for broadcasting a packet such that every node in the network receives it. Often this subset is called the forwarding set. Below are brief descriptions of the various neighbour-knowledge-based schemes.

1) Forwarding Neighbours Schemes:

In forwarding neighbours schemes, the forwarding status of each node is determined by its neighbours. Specifically, the sender proactively selects a subset of its 1-hop neighbours as forwarding nodes. The forwarding nodes are selected using a connected dominating set (CDS) algorithm and the identifiers (IDs) of the selected forwarding nodes are piggybacked on the broadcast packet as the forwarder list. Each designated forward node in turn designates its own list of forward nodes before forwarding the broadcast packet. The Dominant Pruning algorithm [7] is a typical example of the forwarding neighbours schemes. Ideally, the number of forwarding nodes should be minimized to decrease the number of redundant transmissions. However, the optimal solution is NP-complete and requires that nodes know the entire topology of the network.

2) SELF PRUNING SCHEMES:

For broadcasting based on a self pruning scheme [7,22], each node may determine its own status as a forward node or non-forward node, after the first copy of a broadcast packet is received or after several copies of the broadcast packet are received. For example the authors of [8] have suggested that each node must have at least 2-hop neighborhood information which is collected via a periodic exchange of "hello" packets among neighbouring nodes. A node piggybacks its list of known 1-hop neighbours in the headers of "hello" packets and broadcast packets and each node that receives the packet construct a list of its 2-hop and 1-hop neighbours that will covered by the broadcast. If the receiving node will not reach additional nodes, it refrains from broadcasting; otherwise it rebroadcasts the packet.

3) SCALABLE BROADCAST ALGORITHM (SBA):

This algorithm requires that all nodes have knowledge of their neighbours within a two hop radius [9]. This neighbour information coupled with the identity of the node from which a packet is received allows a receiving node to determine if it would reach additional nodes by forwarding the broadcast packet. 2-hop neighbour information is achievable via a periodic exchange of "hello" packets; each "hello" packet contains the node's identifier and the list of known neighbours. After a node receives a "hello" packet from all its neighbours, it has 2-hop topology information centered at itself.

4) MULTIPOINT RELAYING ALGORITHM:

In multipoint relaying [10], each node selects a small subset of its 1-hop neighbours as Multipoint Relays (MPRs) sufficient to cover its 2-hop neighborhood (see Figure 2). When a broadcast packet is transmitted by a node, only the MPRs of a given node are allowed to forward the packet and only their MPRs forward the packet and so on. Using some heuristics, each node is able to locally compute its own MPRs based on the availability of its neighborhood topology information. The neighborhood topology information is obtained via a periodic exchange of "hello" packets among neighbouring nodes. Each "hello" packet contains the sender's ID and its list of neighbours.

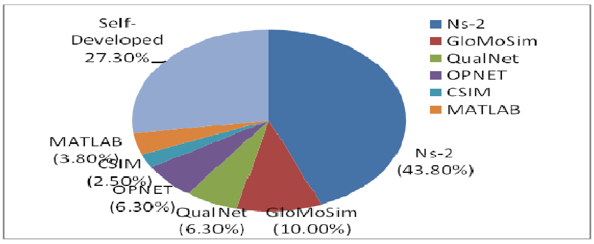

Fig 2. Simulator usage from MobiHoc survey for 2000-2005.

D. CLUSTER-BASED METHODS

In cluster-based broadcast methods [21], the network is partitioned into several groups of clusters forming a simple backbone infrastructure. Each cluster has one cluster head that dominates all other members in the cluster, e.g. is responsible for forwarding packets and selecting forwarding nodes on behalf of the cluster. Two or more overlapping clusters are connected by gateway nodes. Although clustering can be desirable in MANETs, the overhead associated with the formation and maintenance of clusters is non-trivial in most cases [11]. Therefore, the total number of transmissions

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(i.e. number of forwarding nodes) is generally used as the cost criterion for broadcasting. Cluster heads and gateway nodes of a given MANET together form a connected dominating set. The problem of finding the minimum number of forwarding nodes that forms the minimum connected dominating set is well known to be NP-complete.

E. PROBABILISTIC BASED METHODS

Probabilistic broadcasting is one of the simplest and most efficient broadcast techniques that have been suggested [3] in the literature. In this approach, each intermediate node rebroadcasts received packets only with a predetermined forwarding probability. To determine an appropriate forwarding probability, Season et al. [12] have suggested the use of random graphs and percolation theory in MANETs. The authors have claimed that there exists a probability value $P_C < 1$, such that by using P_C as a forwarding probability, almost all nodes can receive a broadcast packet, while there is not much improvement on reachability for $p > P_C$. Since P_C is different in various MANET topologies, and there is no existing mathematical method for estimating P_C, many probabilistic approaches use a predefined value for P_C.

The advantage of probabilistic broadcasting over the other proposed broadcast methods [3, 4,] is its simplicity. However, studies [3] have shown that although probabilistic broadcast schemes can significantly reduce the degrading effects of the broadcast storm problem [3], they suffer from poor reachability, especially in a sparse network topology. But the authors in [13] have argued that the poor reachability exhibited by the probabilistic broadcast algorithms in is due to assigning the same forwarding probability at every node in the network.

Cartigny and Simplot [14] have described a probabilistic scheme where the forwarding probability p is computed from the local density n (i.e. the number of neighbours of the node considering retransmission). The authors have also introduced a fixed value parameter k to achieve high reachability. This broadcast scheme has a drawback of being locally uniform. This is because each node in the network determines its forwarding probability based on the fixed efficiency parameter k which is not globally optimal. hang and Agrawal [15] have described a dynamic probabilistic scheme using a combination of probabilistic and counter-based approaches. In this approach, the forwarding probability at a node is set based on the number of duplicate packets received at the node. But the value of a packet counter at a node does not necessarily correspond to the exact number of neighbours of the node, since some of its neighbours may have suppressed their rebroadcasts according to their local rebroadcast probability.

In [13], the network topology is logically partitioned into sparse and dense regions using the local neighborhood information. Each node located in a sparse region is assigned a high forwarding probability whereas the nodes located in the dense regions are assigned low forwarding probability.

III. ANALYSIS OF PROBABILISTIC ROUTE DISCOVERY

To minimize the overhead associated with the dissemination of broadcast packets in “pure” broadcast scenarios while still maintaining an acceptable level of reachability, probabilistic approaches have been proposed in the literature as an alternative to simple flooding [3, 13, 20]. 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 algorithm. All forwarding node is assigned the same forwarding (fixed probability) probability p and when p = 1 the probabilistic scheme reduces to simple flooding.

An algorithmic framework for probabilistic route discovery

Algorithm: Fixed Probabilistic Route Discovery

```
Upon receiving a RREQ packet rq a node
If RREQ is received for first time
Set rebroadcast probabilistic to p=Pc
Endif
Generate a random number Rnd over the range [0,1]
If Rnd <= p
Broadcast the RREQ packet
Else
Drop the packet
```

The effects of network density and nodal mobility on probabilistic flooding in a pure broadcast scenario have been analyzed over a wide range of forwarding probabilities [13]. The authors have shown that probabilistic broadcast algorithms can achieve improvements in terms of saved rebroadcast in high mobility and dense networks. However, to the best of my knowledge, there has not been a study that evaluates the performance impact of probabilistic broadcast on practical applications such as route discovery over a wide range of forwarding probabilities and varying network operating conditions, notably, network density, node mobility, traffic load and network size.

Motivated by the above observations, the main objective of this chapter is to conduct an extensive performance analysis by means of Ns-2 [16] simulations of probabilistic route discovery in two popular on-demand routing protocols, namely AODV [17] and DSR [18]. In the case of probabilistic route discovery, each received RREQ packet is forwarded once with the forwarding probability p (see Table 3.1). The performance analysis is conducted over a range of forwarding probabilities from 0.1 to 1 in steps of 0.1. This simulation study is the first evaluation to be reported in the literature and will help to provide insight into the potential performance discrepancies of the two routing protocols and, more

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significantly, to outline the relative performance of the various forwarding probabilities under varying network operating conditions. 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.

IV. PERFORMANCE EVALUATION

The performance of fixed probability based broadcast has been evaluated in NS-2 Simulator by using traditional AODV and DSR routing protocols. The NS-2 simulation model consists of 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. Other simulation parameters used in this research study have been summarized in table 2.

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

Simulation	Value
Simulator	NS-2
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

In Figure 3 the contact of node mobility on the performance of FP-AODV and FP-DSR in terms of the routing overhead against the forwarding probability, the routing overhead incurred by FP-AODV and FP-DSR increases with increased node mobility. If increased the node mobility, it will increase the number of broken links and the failure of some route request packets to reach their destinations. Such failures cause another round of route request packet generation and dissemination. 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.

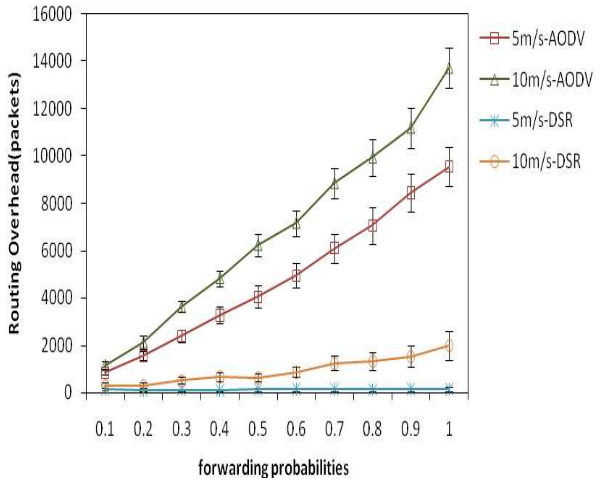

Fig. 3. Routing overhead vs. forwarding probabilities of 150 nodes

In Figure 4 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.

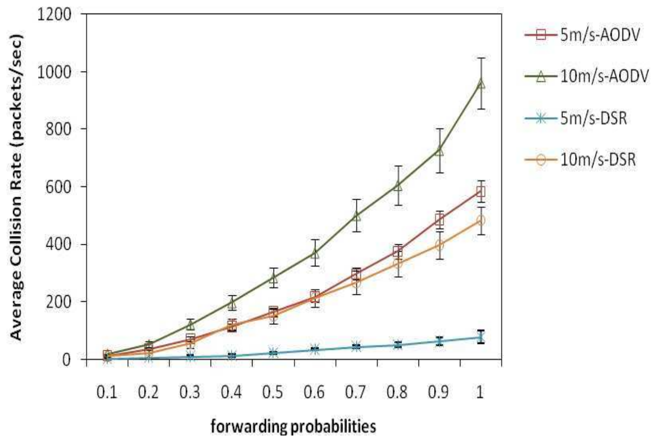

Fig .4. Collision rate vs. forwarding probabilities of 150 nodes

Figure 4 shows the connectivity success ratio of FP-AODV and FP-DSR for 5m/sec and 10m/sec against the forwarding probability. For FP-AODV, the connectivity success ratio of both speeds first increases as the forwarding probability 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. High connectivity of FP-DSR starts to drop after p 0.2. The results in Figure 4.3 also reveal that FP-DSR outperforms FP-AODV in both mobility cases across all forwarding probabilities.

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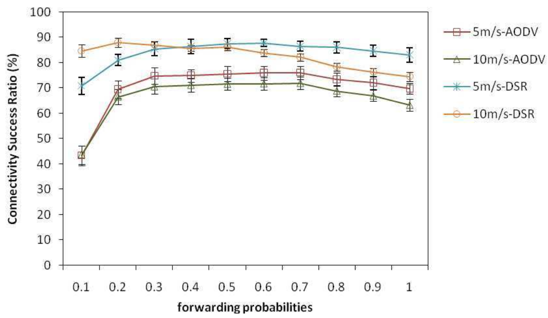

Fig.5. Network connectivity vs. forwarding probabilities of 150 nodes

Figure 5 shows throughput in both FP-AODV and FP-DSR versus the forwarding probability for different maximum speed. It can be seen in Figure 3.10 that for 5m/s and 10m/s, the normalized 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 normalized 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 4.3, the normalized throughput is lower than FP-AODV. This is because some of the routes used for the data transmission in FP-DSR are stale.

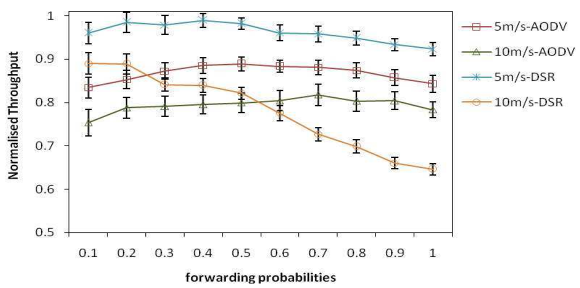

Fig.6.Throughput vs. forwarding probabilities of 150 nodes

The figure 6 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.

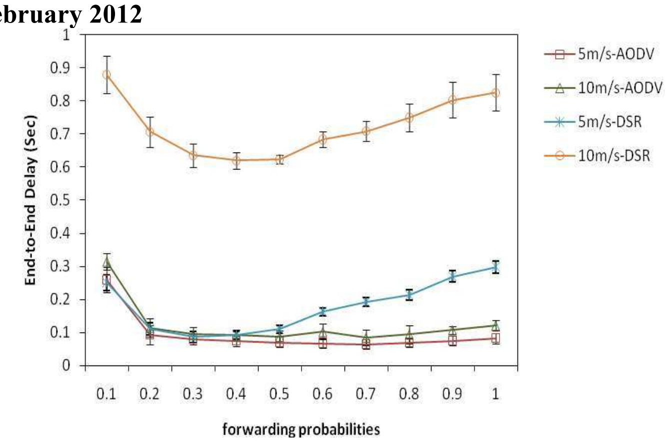

Fig.7. End-to-end delay vs. forwarding probabilities of 150 nodes

V. CONCLUSION

This chapter has conducted the first 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 analysis has been conducted through studying the effects of different node mobility 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 result shows the probabilistic based broadcast is better than simple flooding. The same kind of evaluation may be examined in against node density, traffic load and other parameters.

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