Performance Analysis of Enhanced Routing Discovery under Different Mobility Models in Mobile Ad-Hoc Networks

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Abstract- **Broadcasting is a basic data dissemination technique, which has a number of applications such as address resolution, route discovery, as well as many other network services. While data broadcasting has many advantages, it introduces some problems known as *broadcast storm problems*, which causing a lot of contention, redundant retransmission and collision. Broadcasting traditionally based on the flooding protocol, a source node sends a packet to all nodes in the network until the desired routs are discovered, which simply overflows the network with high number of rebroadcast packets. In this paper our objective is to reduce the number of retransmission in the broadcast as well as to obtain less number of collisions in the network. A good probabilistic broadcast protocol can achieve high save rebroadcast, low collision and less number of relays. This paper improves the performance of existing routing protocols by reducing the communication overhead incurred during the route discovery method by implementing a new broadcast algorithm called the modified probabilistic flooding on the Ad-Hoc on Demand Distance Vector (AODV) protocol. In this paper, we propose a probabilistic approach that calculates the rebroadcast probability according to the number of neighbour's nodes distributed in the ad hoc network for routing request packets (RREQs). The performance of the proposed approach is investigated and compared with the simple AODV, adjusted probabilistic flooding [4,7] and dynamic probabilistic flooding [18] using the GloMoSim network simulator under different mobility models. The performance results reveal that the improved approach is able to achieve higher saved rebroadcast and low collision as well as less number of relays than the adjusted probabilistic flooding [4,7] , dynamic probabilistic flooding [18]and simple AODV.**

1. INTRODUCTION

Ad hoc networks are a set of wireless mobile nodes which communicate with each another. Nodes communicate with each other without relying on any pre-existing routing infrastructure for communication, but instead communicate either directly or with the help of other intermediate nodes in the network. The disseminated, wireless and self-configuring character of ad hoc networks make them appropriate for a wide variety of applications. Ad hoc networks are helpful in many situations where unprepared communication facilities are required, such as disaster relief missions and battlefield communication facilities [1, 2]. Other applications of MANETs are in data acquisition in hostile territories, virtual classrooms, and temporary local area networks.

Broadcasting is a general and basic operation in ad hoc networks whereby a source node transmits a packet so that each node in a network receives a copy of this packet. In the one-to- all models, transmission by each node can reach all nodes that are within its transmission radius, while in the one-to-one model, each transmission is directed toward only one neighbour using narrow beam directional antennas or separate frequencies for each node. Broadcasting is also a common operation in many distributed computing applications and can be used for service or resource discovery in unstructured environments [1,8]. For example, in Ad Hoc On-demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR), Zone Routing Protocol (ZRP) [11], and Location Aided Routing (LAR) [8], in the network a route request is broadcasted. Every node remains the broadcast ID and the name of the node from which the message has been received. As soon as the correspondent is reached, it replies with a unicast (point-to-point) message and then each intermediate mobile node is capable to establish the return route.

Flooding is commonly used for broadcasting. Each node, that receives a broadcast message for the first time, rebroadcasts it to its neighbours [6]. The only 'optimisation' applied to this technique is that nodes remember broadcast messages received and do not rebroadcast if they receive repeated copies of the same message [11]. This is very simple and needs only some resources in the nodes. This approach offers the advantage to be reliable, but produces a high overhead in the network. The probability of multiple requests at the same time for medium access is very high and the number of collisions dramatically increases, which causes a lot of dropped packets, such a scenario has often been referred to as the broadcast storm problem [5, 6, 7]. A number of researchers have identified this problem by showing how serious it is through analyses and simulations [6]. A probabilistic approach for flooding has been suggested in [8, 9, 10] as a means of reducing redundant rebroadcasts and alleviating the broadcast storm problem. In the probabilistic scheme, when receiving a broadcast message for the first time, a node rebroadcasts the message with a pre-determined probability *p*; every node has the same probability to rebroadcast the message. When the probability is 100%, this scheme reduces to simple flooding. The studies of [5] have shown that probabilistic broadcasts incur significantly lower overhead compared to blind flooding while maintaining a high degree of propagation for the broadcast messages.

More solutions include probabilistic (gossip-based) [15, 2], counter-based [2], distance-based [2, 6], location-based [2] and cluster-based [2, 6]. In the probabilistic schemes, a host rebroadcasts the message with a fixed probability *P*. The counter-based scheme broadcasts message when the number of received copies at the host is less than a threshold.

One of the important problems in the ad hoc network is to reduce the number of necessary message for broadcast. In this paper, we propose probabilistic broadcast approach that can efficiently reduce broadcast redundancy in mobile wireless networks where the forwarding probability p is dynamically adjusted by the local topology information. Topology information is obtained by proactive exchange of “HELLO” packets between neighbours.

Three significant matrices to measure network performance, saved rebroadcasts, collision and relays are used under different mobility models.

We evaluate our proposed approach against the simple AODV, adjusted probabilistic flooding [4,7] and dynamic probabilistic flooding [18] by implementing them in a modified version of the AODV protocol. The simulation results show that broadcast redundancy can be significantly reduced through the proposed approach in all mobility scenarios.

The rest of this paper is configured as follows: Section 2 introduces the background and related work of broadcasting in MANETs. In section 3, we present the proposed dynamic probabilistic approach, highlighting its distinctive features from the other similar techniques. Section 4 provides an overview of different mobility models in MANETs. The parameters used in the experiments and the performance results and analyses of the behaviour of the broadcasting algorithm are presented in Section 5. Section 6 concludes the paper and suggestions for the future work.

2. RELATED WORK

Flooding is one of the earliest broadcast mechanisms in wired and wireless networks. Upon receiving the message for the first time, each node in the network rebroadcasts a message to its neighbours. While flooding is simple and easy to implement, it can affect the performance of a network, and may lead to a serious problem, often known as the *broadcast storm problem* [2, 6] which is exemplified by large number of redundant rebroadcast packets, collision and network bandwidth contention. Ni *et al* [2] have studied the flooding protocol experimentally and analytically. Their results have indicated that rebroadcast could provide at most 61% additional coverage and only 41% additional coverage in average over that already covered by the previous broadcast attempt. Consequently, they have concluded that retransmits are very costly and should be used with warning. Authors in [2] have classified existing broadcasting techniques into five classes with respects to their ability to reduce contention, collision, and redundancy. The classes consist of probabilistic, distance-based, counter-based, cluster-based and location-based. For each of these classes a brief description is provided in the following. In the probabilistic scheme, a host node rebroadcasts messages according to a certain probability. The distance-based scheme uses the relation distance between a host node and the previous sender to make a decision whether to rebroadcast a message or not. In the counter-based scheme, a node determines whether to rebroadcast a message or not by counting how many the same messages, it has received during a random period of time. The counter based scheme supposes that the expected additional coverage is so small that rebroadcast would be ineffective when the number of recipient broadcasting messages exceed a certain threshold value. The cluster-based scheme divides the ad hoc network into several clusters of mobile nodes. Every cluster has one cluster head and a number of gateways. The cluster head is a representative of the cluster whose rebroadcast can cover all hosts in that cluster. Only gateways can communicate with other clusters and have responsibilities to disseminate the broadcast message to other clusters.

The location-based scheme rebroadcasts the message if the additional coverage due to the new emission is larger than a certain pre-fixed bound.

Another classification for broadcasting techniques in MANETs also could be found in [6]. This study has classified the broadcasting techniques into the following four categories: simple flooding, probability-based, area-based, and neighbour knowledge schemes. In the flooding scheme, each node rebroadcasts to its neighbours as a response to every recently received message. The probability-based scheme is a very simple method of controlling message floods. Every node rebroadcasts with a fixed probability *p* [10]. Clearly when *p*=1 this scheme be similar to simple flooding. In the area based scheme, a node determines whether to rebroadcast a packet or not by calculating and using its additional coverage area [2]. Neighbour knowledge scheme [6] maintains neighbour node information to decide who should rebroadcast. This method requires mobile hosts to explicitly exchange neighbourhood information among mobile hosts using periodic Hello packets. The neighbour list at the present host is added to every broadcast packet. When the packets arrive at the neighbours of the present host, every neighbour compares its neighbour list with the list recorded in the packets. It rebroadcasts the packets if not all of its own neighbours are included in the list recorded in the packets. The length of the period affects the performance of this approach. Very short periods could cause contention or collision while too long periods may debase the protocol’s ability to deal with mobility.

Cartigny and Simplot [1] have described a probabilistic scheme where the probability *p* of a node for retransmitting a message is computed from the local density *n* (i.e., the number of neighbours) and a fixed value *k* for the efficiency parameter to achieve the reachability of the broadcast. This technique has the drawback of being locally uniform. In fact, each node of a given area receives a broadcast and determines the probability according to a constant efficiency parameter (to achieve some reachability) and from the local density [1].

Zhang and Dharma [3,18] have also described a dynamic probabilistic scheme, which uses a combination of probabilistic and counter-based schemes. This scheme dynamically adjusts the rebroadcast probability *p* at every mobile host according to the value of the packet counters. The value of the packet counter does not necessarily correspond to the exact number of neighbours from the current host, since some of its neighbours may have suppressed their rebroadcasts according to their local rebroadcast probability. On the other hand, the decision to rebroadcast is made after a random delay, which increases latency.

Bani Yassein et al. [4,7] have proposed fixed pair of adjusted probabilistic broadcasting scheme where the forwarding probability *p* is adjusted by the local topology information. Topology information is obtained by proactive exchange of "HELLO" packets between neighbours to construct a 1-hope neighbour list at every host.

Hanashi, A. M. et al. [18] have proposed a probabilistic approach that dynamically calculates the rebroadcast probability according to the number of neighbour's nodes distributed in the ad hoc network for routing request packets (RREQs). In this algorithm since they have $p_{\max}{}^{n}$ for this term will get close to zero as (n_{nbr}) get large so the value of rebroadcast probability (*p*) does not depend on the exact number of neighbours node of the host node in all cases, so the decision to rebroadcast is made after certain time, which increase the latency.

With the broadcasting methods described above, the simplest one is flooding, which also produces the highest number of redundant rebroadcasts. The probabilistic approaches reduce the number of rebroadcasts at the expense of reachability. Counter-based algorithms have better reachability and throughput, but suffering from relatively longer delay. Area-based algorithms need support from GPS or other location devices. Here, we propose a new probabilistic broadcast approach that can efficiently reduce broadcast redundancy in mobile wireless networks where the forwarding probability p is dynamically adjusted by the local topology information. Topology information is achieved by proactive swap of "HELLO" messages between neighbours. We describe the details of our approach in the following section.

3. PROBABILISTIC ALGORITHMS

As studied previously, traditional flooding suffers from the redundant message reception problem [2]. The same message is received several times by each node, which is inefficient, wastes valuable resources and can cause high contention in the broadcasting medium. In fixed probabilistic flooding the rebroadcast probability p is fixed for every node [10]. This method is one of the alternative approaches to flooding that aims to limit the number of redundant transmissions. In this scheme, when receiving a broadcast message for the first time, a node rebroadcasts the message with a pre-determined probability p. Thus every node has the same probability to rebroadcast the message, regardless of its number of neighbors.

In dense networks, multiple nodes share similar transmission ranges. Therefore, these probabilities control the number of rebroadcasts and thus might save network resources without affecting delivery ratios. Note that in sparse networks there is much less shared coverage; thus some nodes will not receive all the broadcast packets unless the probability parameter is high. Therefore, setting the rebroadcast probability *P* to a very small value will result in a poor reachability. On the other hand, if *P* is set to a very large value, many redundant rebroadcasts will be generated.

A brief outline for the proposed probabilistic flooding algorithm is shown below and works as follows. On hearing a broadcast packet (*pkt*) at host node *N*, the node rebroadcast a message according to a high probability *P* if the *pkt* is received for the first time, and the number of neighbours of ith node is less than average number of neighbours (threshold value). Hence, if ith node has a low degree (as measured by the number of neighbours), retransmission should be likely. Otherwise, if ith node has a high degree its rebroadcast probability *P* is set low.

Our proposed algorithm is a combination of the probabilistic and knowledge based approaches. It dynamically adjusts the re-broadcast probability *P* at every mobile node according to the value of the local number of neighbours. We calculate the average number of neighbours for the selection of the value of *P* by using equation 1[4,7]. Let A be the area of an ad hoc network, N be the number of mobile nodes in the network. The average number of neighbour can be obtained as shown below.

$$\overline{nbr} = \left(N-1\right) \times 0.8 \times \frac{\pi r^2}{A} \qquad (1)$$

<u>Enhanced probabilistic broadcasting algorithm</u>

This algorithm relays the packet (pkt) for ith node with probability *P*.

Input Parameters:

pkt : Packet to relay by ith node.

p(i): Rebroadcast probability of packet (pkt) of ith node.

$RN\ (i)$: Random Number for ith node to compare with the rebroadcast probability *p*.

$S_{nbr}\ (i)$: Number of neighbour nodes of ith node.

$\overline{nbr}$: Average number of neighbour (threshold value).

$nbrTable(i)$: Neighbour table for i^{th} node

Output Parameters:

$Discpkt\ (i)$: Packet (pkt) will be discarding by the ith node, if it is already in its list.

$Rbdpkt\ (i)$: Packet (pkt) will be rebroadcast by ith node, if probability p is high.

$Drpkt(i)$: Packet (pkt) will be dropped by ith node, if probability p is low.

Calculation of Broadcasting probability upon receiving a braodcast packet (pkt)

```
if a packet (pkt) is received for the $1^{st}$ time at the $i^{th}$ node then
  {
    get nbrTable(i)
     if size (nbr Table(i)) = = 0 then
     return (0)
     else
       {
         If ( $S_{nbr}(i) < \overline{nbr}$ ) then
ith node  has a low degree:
$P := \prod_{i=0}^{S_{nbr}(i)} P * P_{\max}$
    if  $p < p_{min}$  then
     $p = p_{min}$
    end if
return (P)
else
ith node  has a high degree:
drop the packet ( $Drpkt(i)$ )
   end if
end if
Generate a random number RN over [0, 1].
Relay the packet ( $Rbdpkt(i)$ ) when ( $P > RN(i)$ )
  else
        $Drpkt(i)$
end if
Where Pmax= 0.9 and Pmin=0.4
```

Neighbour informed that nbrTable(i) for ith node is formed by sending periodic hello packets and entries in the table are updated based on the replies received from neighbours.

4. MOBILITY MODELS

Appropriate mobility models that can accurately capture the properties of real-world mobility patterns are required for effective and reliable performance evaluation of the MANETs. Due to the different types of movement patterns of mobile users, and how their location, velocity and acceleration change over time, different mobility models should be used to emulate the movement pattern of targeted real life applications. In our study, three different mobility models are considered including Random Waypoint (RWP), Manhattan Grid and Reference Point Group Mobility (RPGM) models.

The RWP mobility model proposed by Johnson and Maltz [13] is the most popular mobility model used in the performance and analysis of the MANETs due to its simplicity. The two main key parameters of the RWP models are $V_{\max}$ and T_{pause} where $V_{\max}$ the maximum velocity for every mobile station and T_{pause} is the pause time. A mobile station in the RWP model selects a random destination and a random speed between $[0, V_{\max}]$, and then moves towards the selected destination at the selected speed. Upon reaching the destination, the mobile station stops for some pause time T_{pause}, and the repeats the process by selecting a new destination, speed and resuming the movement. Figure 1 shows a movement trace of a mobile station using a RWP mobility model.

Unlike RWP mobility, Manhattan mobility model uses a grid road topology as shown in Figure 2. Initially, the wireless stations are placed randomly of the edge of the graph. Then the wireless stations move towards a randomly chosen destinations employing a probabilistic approach in the selection of stations movements with probability ½ to keep moving in the same direction and ¼ to turn left or right.

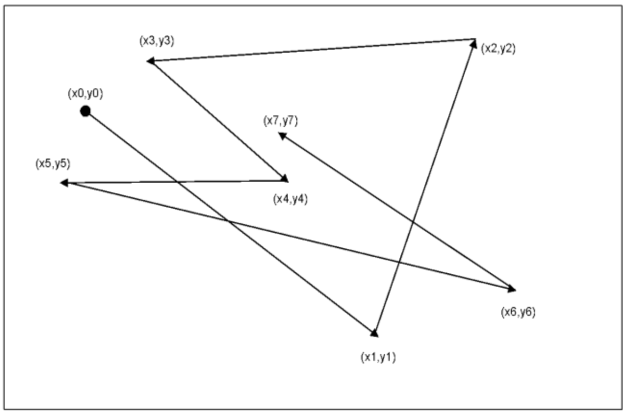

Fig.1. An example of mobile station movement in RWP model.

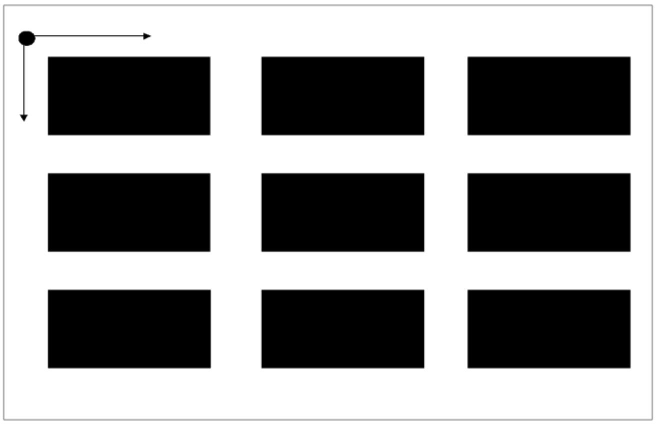

Fig. 2. Example of mobile station movement in Manhattan mobility model.

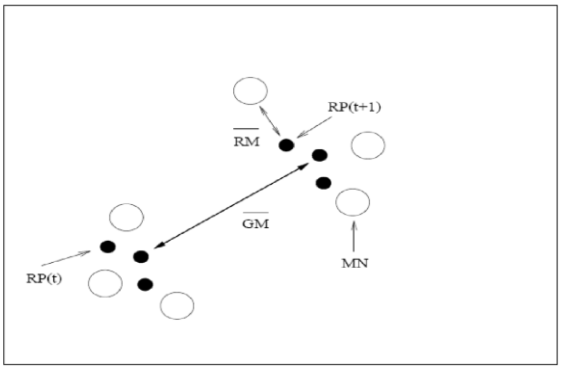

Fig.3 An example of node movement in RPG Mobility Model

In addition to RWP and Manhattan mobility models, the Reference Point Group Mobility (RPGM) model is proposed in [17]. In this model, each group has a number of wireless station members and a center, which is either a logical center or a group leader.

This model represents the random motion of a group of mobile nodes (MNs) as well as the random motion of every individual MN within the group. The group leader movement determines the mobility behaviors of all other members in the group. The group leader is used to calculate group motion via a group movement vector, $\overline{GM}$. The movement of the group centre completely characterizes the movement of its corresponding group of MNs, including their direction and speed. Individual MNs randomly move about their own predefined reference points, whose movements rely on the group movement. As the individual reference points move from time t to t+1, their locations are updated according to the group's logical centre. Once the updated reference points, RP(t+1), are calculated, they are combined with a random motion vector, $\overline{RM}$, to represent the random motion of each MN about its individual reference point. Figure3 shows an example of node movement in Reference Point Group Mobility Model. One of the real applications which RPGM model can represent it accurately is the mobility behaviors of soldiers moving together in a group.

5. PERFORMANCE ANALYSES

In this section, we evaluate the performance of the proposed dynamic probabilistic broadcasting algorithm. We compare the proposed algorithm with the simple AODV, adjusted probabilistic flooding [4,7] and dynamic probabilistic flooding algorithm [18]. The metrics for comparison include saved rebroadcast, average number of routing request rebroadcasts, and the number of collisions.

A. Simulation Setup

The GloMoSim network simulator (version 2.03) [9] has been adopted to conduct extensive experiments to evaluate behavior of the proposed probabilistic flooding algorithm. We study the performance of the broadcasting approaches in the situation of higher level application, namely, the AODV routing protocol [8,10,11] that is included in the GloMoSim package. The original AODV protocol uses simple blind flooding to broadcast routing requests. We have implemented three AODV variations: one using adjusted probabilistic flooding [4, 7] method called AD-AODV (AODV + fixed pair probability), the second one based on dynamically calculating the rebroadcast probability for each node [18], called P-AODV (AODV + dynamic probability) and the third one is our Enhanced dynamic algorithm (EDP-AODV). In our simulation, we use a 1000m × 1000m area with different number of connections and 100 nodes. The network bandwidth is 2 Mbps and the medium access control (MAC) layer protocol is IEEE 802.11[3]. Other simulation parameters are shown in Table1.

The main idea behind the proposed approach is to reduce the rebroadcasting number in the route discovery phase, thus reducing the network traffic and decrease the probability of channel contention and packet collision.

TABLE1. SIMULATION PARAMETERS

Simulation Parameter	Value
Simulator	GloMoSim v2.03
Network Range	1000m×1000m
Transmission Range	250m
Mobile Nodes	100
Traffic Generator	CBR
Band Width	2Mbps
Packet size	512Bytes
Packet Rate	10 pps
Simulation time	900s

Since our algorithm is based on a probabilistic approach, it does not fit every scenario, as there is a small chance that the route requests cannot reach the destination. It is necessary to re-generate the route request if the previous route request failed to reach the destination. We study the performance of the broadcast approaches in these scenarios and we run the simulation for 50 times.

B. Saved Rebroadcast (SRB)

In our algorithm, the rebroadcast probability is dynamically adjusts the rebroadcast probability *p* at each mobile host according to the value of the local number of neighbours. The value of *p* changes when the host moves to a different neighbourhood. In a sparser area, the rebroadcast probability is larger and in denser area, the probability is lower. SRB is the ratio of the number of route request (RREQs) packets rebroadcasted over total number of route request (RREQs) packets received, excluding those expired by time to live (TTL).

As an effort to investigate the performance of our proposed dynamic probabilistic algorithm, fig.4, fig.5 and fig.6 compare the saved rebroadcast of the adjusted probabilistic flooding [4,7], dynamic probabilistic flooding [18] and enhanced dynamic probabilistic under three different mobility models scenarios. For the RWP scenario (fig.4), our improved algorithm can perform a better SRB for network with different number of source-destination pair's connections with 100 nodes and achieves a higher saved rebroadcast than other schemes.

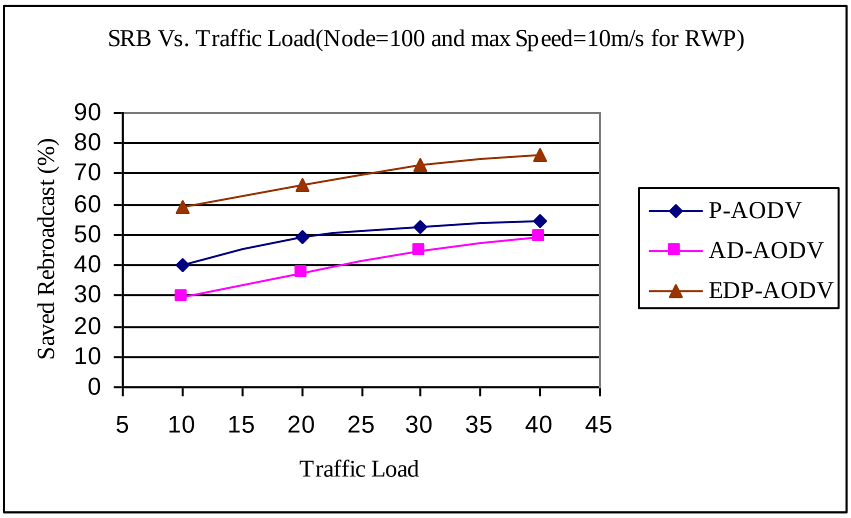

Fig.4. Saved Rebroadcast comparison between our proposed dynamic probabilistic and adjusted probabilistic flooding and dynamic probabilistic flooding for the RWP mobility model.

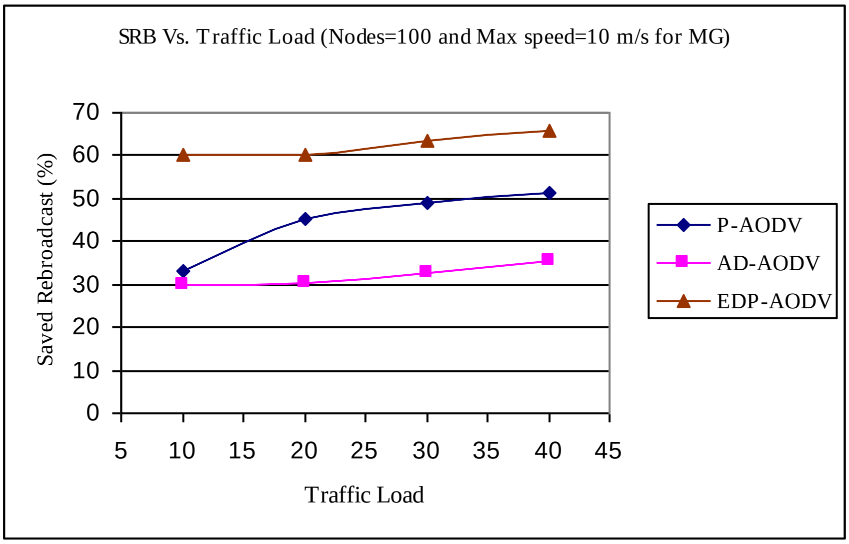

Fig.5. Saved Rebroadcast comparison between our proposed dynamic probabilistic and adjusted probabilistic flooding and dynamic probabilistic flooding for the Manhattan mobility model.

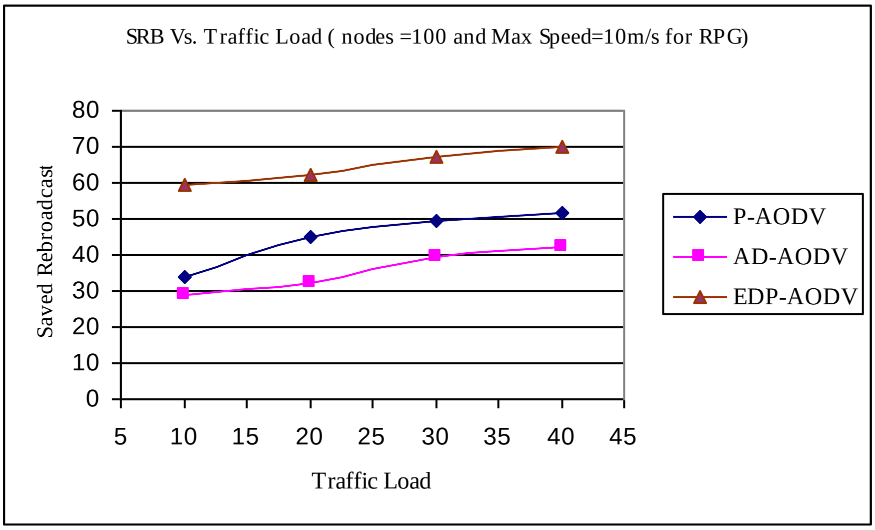

Fig.6. Saved Rebroadcast comparison between our proposed dynamic probabilistic and adjusted probabilistic flooding and dynamic probabilistic flooding for the RPGM mobility model.

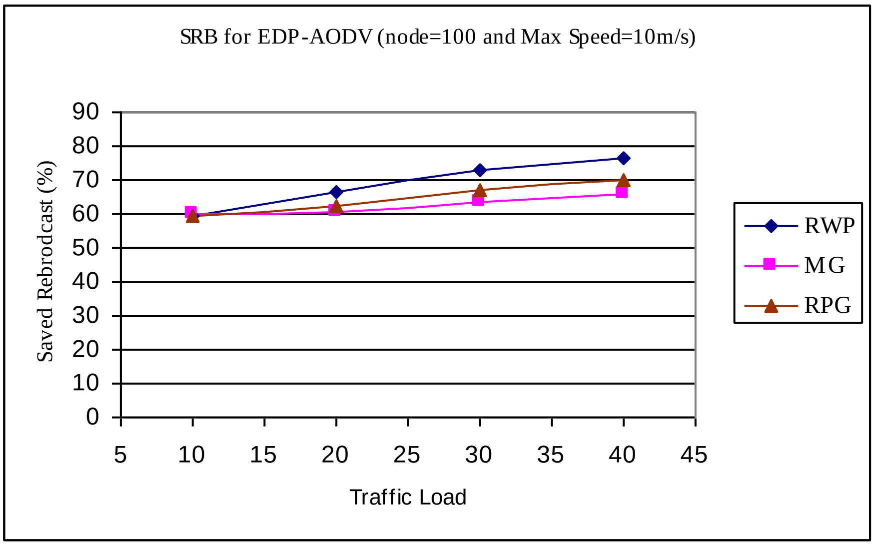

Fig.7. Comparison of Saved Rebroadcast for our proposed probabilistic under RWP, MG and RPGM mobility model.

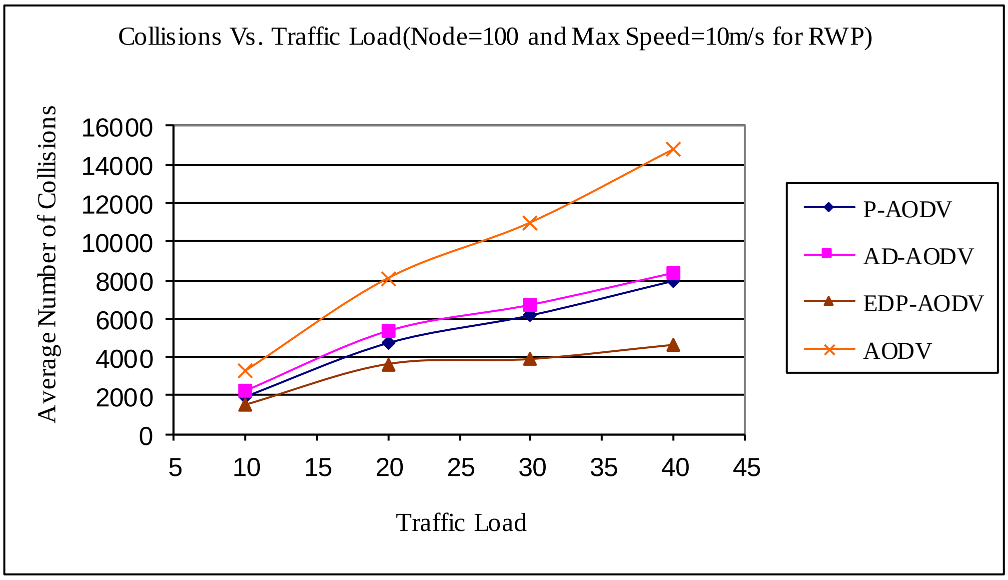

Fig.8. collision comparison between our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the RWP mobility model.

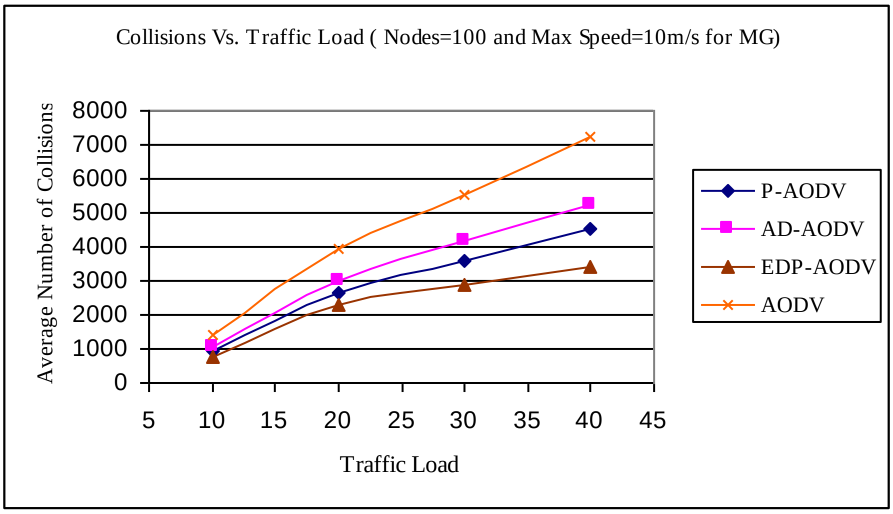

Fig.9. collision comparison between our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the Manhattan mobility model.

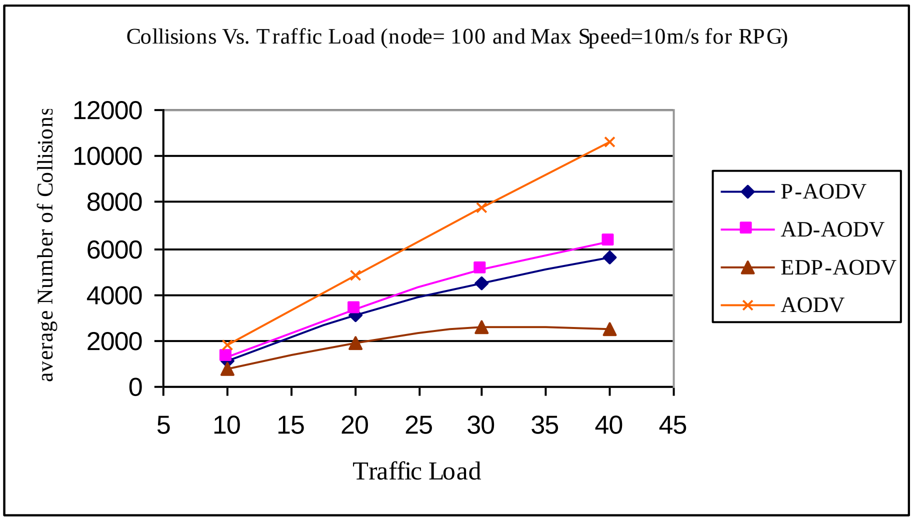

Fig.10.Collision comparison between our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the RPGM mobility model.

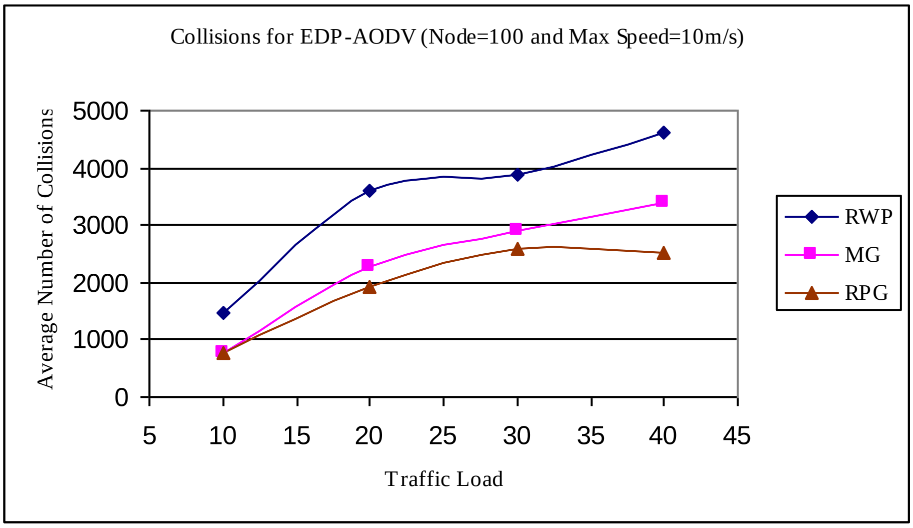

Fig.11.Comarison of collision for our proposed probabilistic under RWP, MG and RPGM mobility model

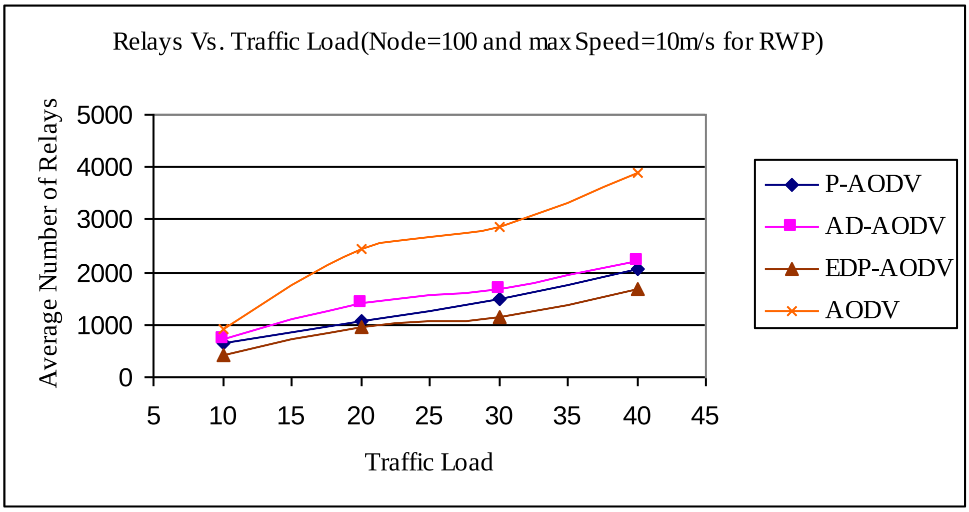

Fig.12. Relays comparison between our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the RWP mobility model.

Moreover, Figure.5 shows the saved rebroadcast of the adjusted probabilistic flooding (AD-AODV) [4,7], dynamic probabilistic flooding (P-AODV) [18] and proposed dynamic probabilistic (EDP-AODV) under Manhattan mobility scenario. As a result for Manhattan mobility model scenario, also our algorithm can achieve better saved rebroadcast than the adjusted probabilistic flooding and dynamic probabilistic flooding.

Furthermore Figure 6 indicates the saved rebroadcast of our algorithm, adjusted probabilistic flooding [4,7] and dynamic probabilistic flooding [18] under RPGM mobility model. From the figure, our algorithm has better achievement than that of the adjusted probabilistic flooding and dynamic probabilistic flooding.

Figure7 also clears that under the RWP mobility model scenario our algorithm archive better saved rebroadcast than the Manhattan and RPG mobility model scenarios. This is because of the different characteristics of the mobility pattern of each model

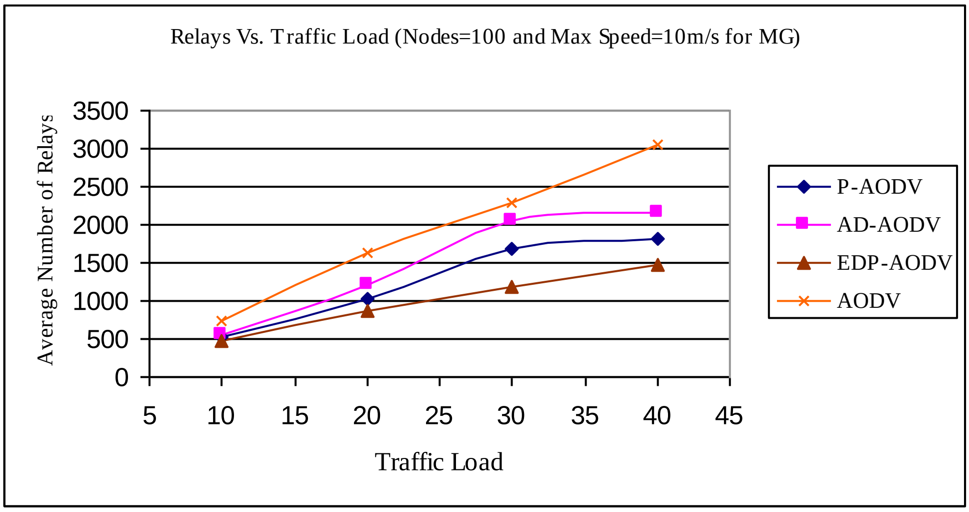

Fig.13. Relays comparison between our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the Manhattan mobility model.

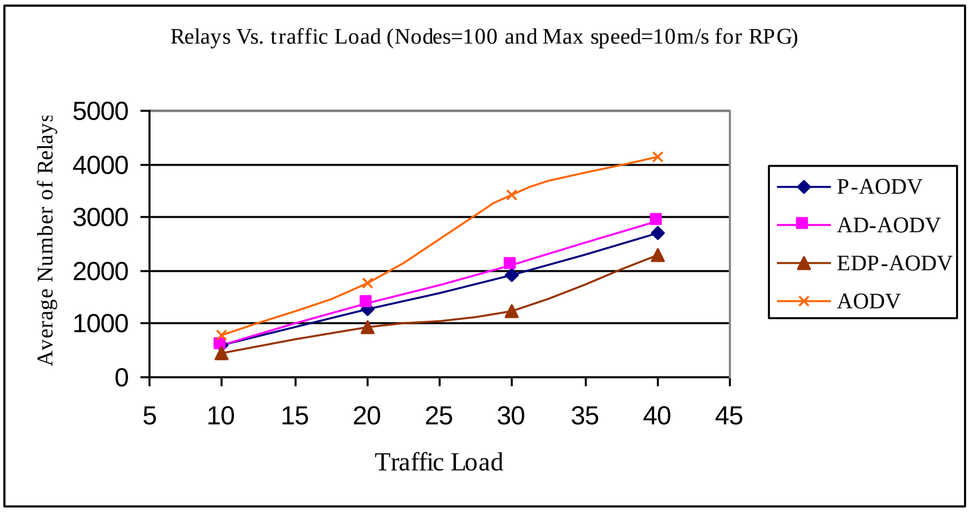

Fig.14. Relays comparison between our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the RPGM model.

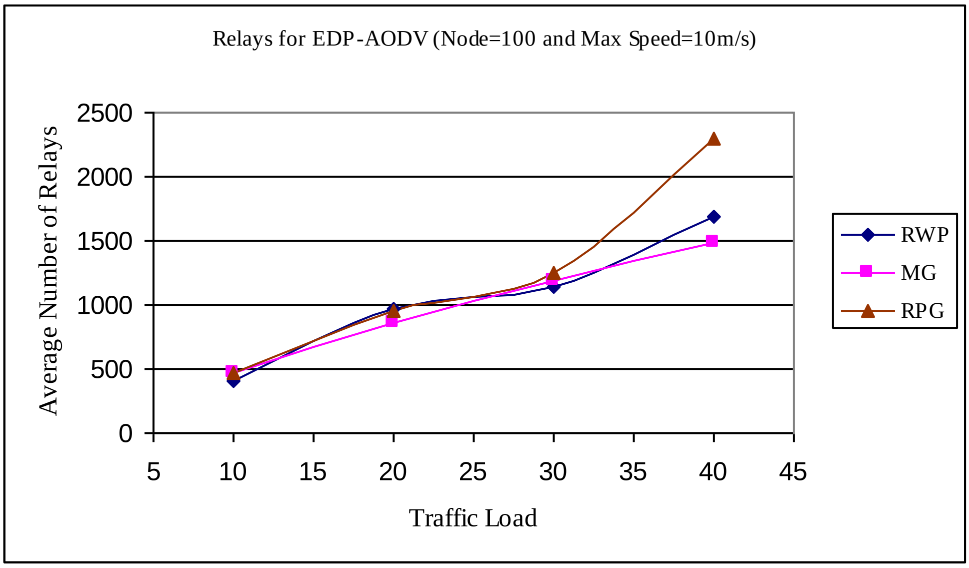

Fig.15. Comparison of Relays for our proposed probabilistic under RWP, MG and RPGM mobility model.

C. Collisions

We measure the number of collisions for these schemes at the physical layer. Since data packets and control packets share the same physical channel, the collision probability is high when there are a large number of control packets. Figs. 8, 9 and 10 represent a comparison of collision between our algorithm (EDP-AODV), P-AODV, AD-AODV and Blind AODV under different mobility models.

As shown in the Fig 8. (RWP scenario), our algorithm incurs fewer numbers of collisions than that of the P-AODV, AD-AODV and Blind AODV.

Moreover, similar behaviour is observed for the scenario of the Manhattan mobility model (Fig.9). Our algorithm achieved less collision compared with the P-AODV, AD-AODV and Blind AODV algorithms.

Additionally, Fig.10 shows the collision of our algorithm, P-AODV, AD-AODV and Blind AODV under RPGM model. As shown in the figure, our algorithm has a lower collision than the P-AODV, AD-AODV and Blind AODV.

It is worth noting that under different mobility models our algorithm outperforms the P-AODV, AD-AODV and Blind AODV. Figure11 indicates that the number of collisions for our proposed probabilistic algorithm under RPG mobility models is significantly lower than that of under RWP and Manhattan Grid mobility models. This is because of the different characteristics of the mobility pattern of each model.

After we introduce mobility, more route requests are generated and some of them may fail to reach their destinations. Such failures cause another round of transmission of route request packets. Figure12 shows the number of relays of our algorithm, P-AODV, AD-AODV and Blind AODV under RWP model. As shown in figure, the proposed algorithm has lower relays numbers than P-AODV, AD-AODV and Blind AODV.

In Figure13, we compare Relays for Manhattan mobility model. The figure shows our algorithm incurs lower number of relays. As a result, for rout request, our scheme can definitely perform better than P-AODV, AD-AODV and Blind AODV in these scenarios.

Figure14 shows the performance with RPGM mobility model. Dou to increasing the number of connections in the network with mobility, more route requests fail to reach the destinations. In these cases, more route requests are generated. The figure implies that our dynamic probabilistic approach can achieve less rout request than P-AODV, AD-AODV and Blind AODV in this mobility model too.

Figure15 shows the number of relays for our algorithm under RWP, RPGM and MG mobility model. The figure indicates that enhanced algorithm under MG mobility model incur lower number of relays than RWP and RPG mobility models.

D. Reachability

Reachability measures are the proportion of nodes which can receive a broadcast packet. A host will miss a packet if all of its neighbours decide to suppress rebroadcasts.Within a network without separation, the flooding scheme guarantees that all nodes can get the broadcast packets at the expense of additional traffic caused by redundant rebroadcasts. In reality, however, redundant rebroadcasts also contribute to possibility of packet collisions that may eventually cause packet drops, thus adversely affecting the reachability.

We randomly choose source–destination node pairs and ensure if a packet can arrive at the destination node from the source node. If there is an existing route from the

source node to the destination node, then the routing request packets broadcast from the source node have arrived at the destination node. We calculate the percentage of the node pairs that have a route between the source and the destination over the total number of selected pairs. This ratio is not exactly equal to the reachability, but it is proportional to the reachability. We use this percentage to compare the reachability with different approaches.

Figure.16 shows the reachability for a network with 100 nodes, 10 m/s maximum speed and 10, 20, 30 and 40 connections of source-destination pairs, respectively for Random waypoint mobility model. The enhanced algorithm, adjusted probabilistic flooding [4,7], dynamic probabilistic flooding [18] and the simple AODV algorithms provide slightly similar reachability results at all Traffic Load connections which are fallen between (93.41-95%).
Figure.17 shows the comparison between our algorithm and other algorithms in terms of reachability for the Manhattan Grid mobility scenario. As shown in the figure the reachability at all traffic load connections for all algorithms is slightly same.

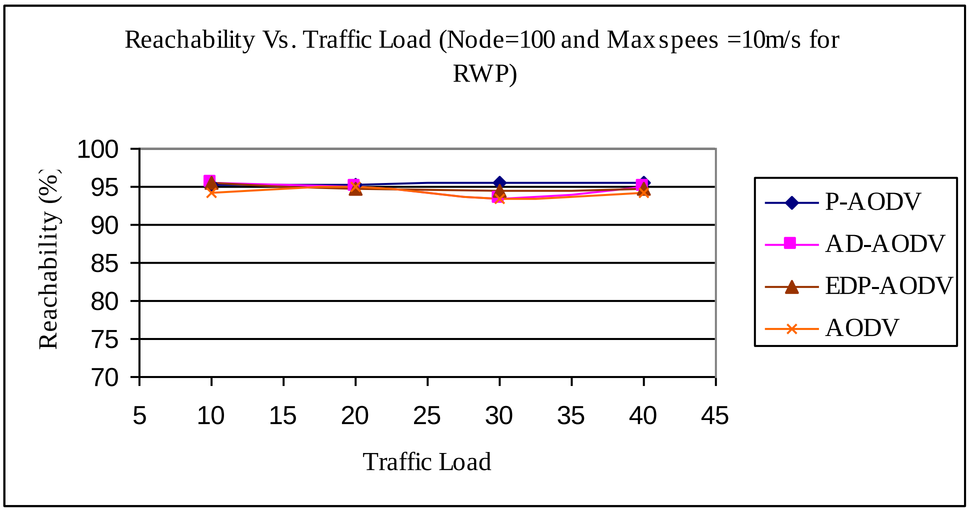

Fig.16. Comparison of reachability for our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the RWP mobility model.

Figure.18 also shows the comparison between our enhanced algorithm, adjusted probabilistic flooding [4,7], dynamic probabilistic flooding [18] and the simple AODV algorithms in terms of reachability for the Reference Point Group mobility scenario. As shown in the figure the reachability at all traffic load connections are fallen between (94.7-96.8%). Moreover the figure shows that dynamic probabilistic flooding [18] (P-AODV) slightly performs better reachability than other algorithms.
Figure19 shows the Reachability for our algorithm (EDP-AODV) under RWP, MG and RPGM mobility models. The figure also obvious that under MG mobility model scenario our algorithm archives better reachability than the RWP and RPG mobility models scenarios.

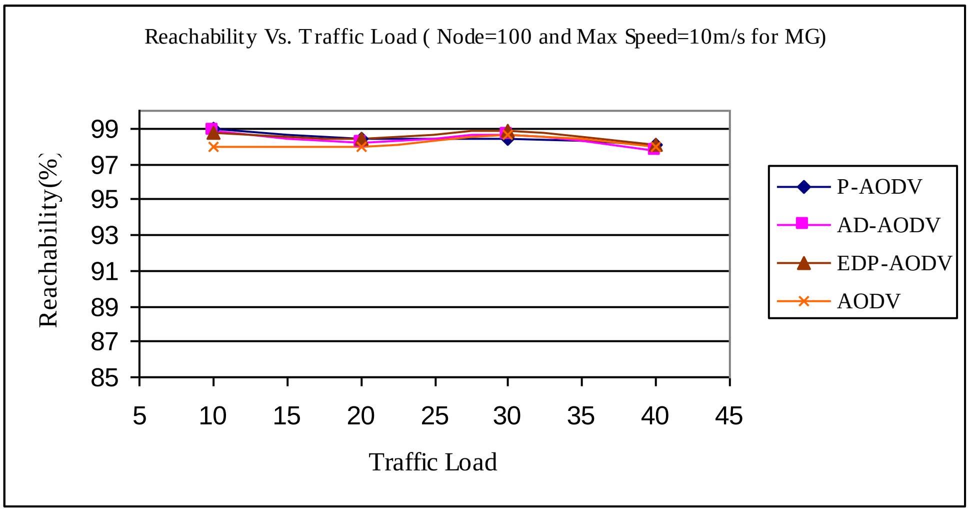

Fig.17. Comparison of reachability for our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the MG mobility model.

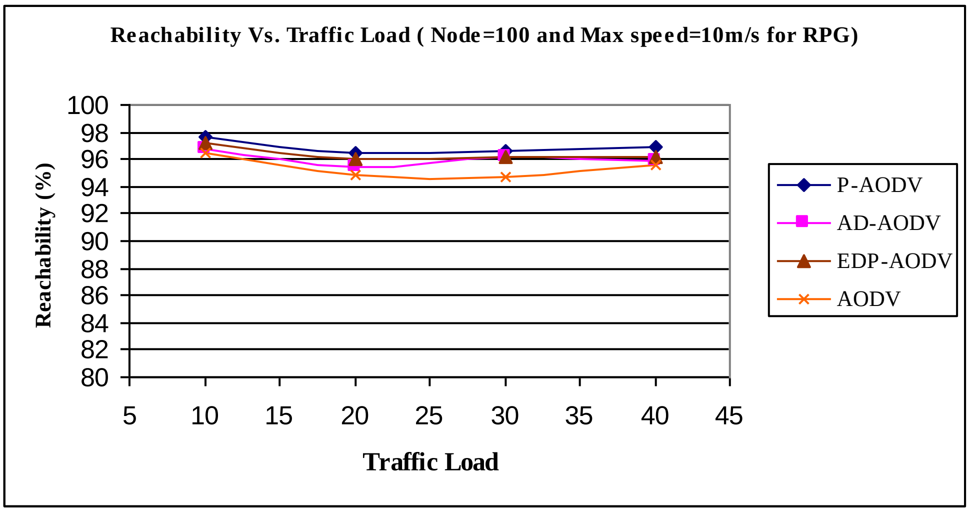

Fig.18. Comparison of reachability for our proposed dynamic probabilistic, adjusted probabilistic flooding, dynamic probabilistic flooding and Blind AODV for the RPG mobility model.

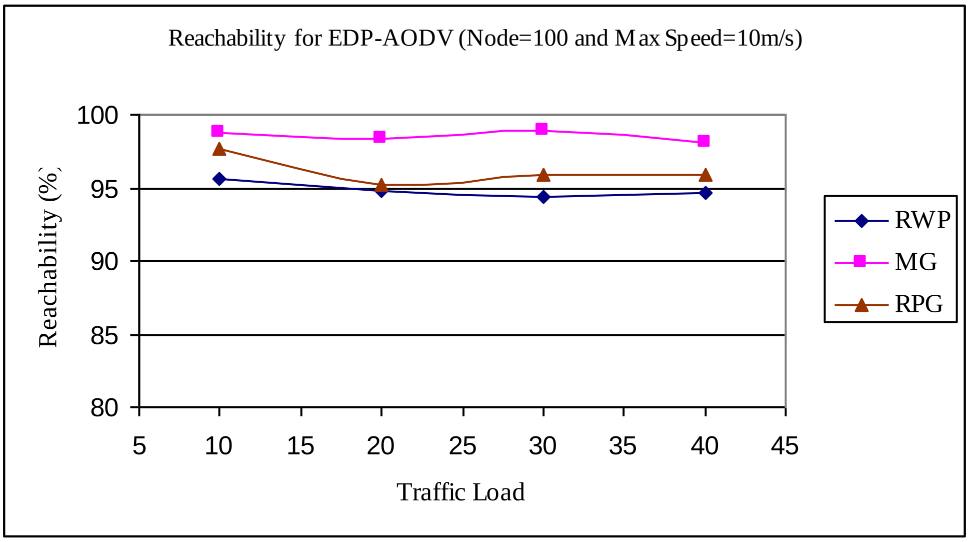

Fig.19. Comparison of Reachability for our proposed probabilistic under RWP, MG and RPGM mobility model.

6. CONCLUSIONS

This paper has evaluated the performance of enhanced probabilistic flooding on the AODV protocol where nodes move according to different mobility models, which traditional uses simple flooding, in order to increase the saved rebroadcast of rout requests. This proposed algorithm decides the rebroadcast probability by taking into account the network density. In order to improve the saved rebroadcasts, the rebroadcast probability of low density nodes is increased while that of high density of mobile nodes is decreased. Compared with P-AODV, AD-AODV and Blind AODV, our simulation results have shown that the proposed probabilistic flooding algorithm outperforms the P-AODV, AD-AODV and Blind AODV in terms of saved rebroadcast, even under conditions of different number of source-destination pair's connections and different mobility models. It also shows lower collision and generates less route request than the P-AODV, AD-AODV and Blind AODV in all mobility scenarios.

For future work it would be interesting to evaluate the Performance of dynamic probabilistic flooding on the Dynamic Source Routing protocol (DSR) with different mobility models representing more realistic scenarios.

We also plan to make an analytic model for our proposed algorithm in order to compare it with simulation results.

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