A Performance Comparison of Smart Probabilistic Broadcasting of Ad hoc Distance vector (AODV)

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Abstract

Broadcast is a common operation used in Mobile Ad hoc Networks (MANETs) for many services, such as, rout discovery and sending an information messages. The direct method to perform broadcast is simple flooding, which it can dramatically affect the performance of MANET. Recently, a probabilistic approach to flooding has been proposed as one of most important suggested solutions to solve the broadcast storm problem, which leads to the collision, contention and duplicated messages. This paper proposed new probabilistic method to improve the performance of existing on-demand routing protocol by reduced the RREQ overhead during rout discovery operation. The simulation results show that the combination of AODV and a suitable probabilistic rout discovery can reduce the average end- to- end delay as well as overhead and still achieving low normalized routing load, comparing with AODV which used fixed probability and blind flooding.

Keywords: MANET, Overhead, Flooding, Simulation, AODV.

1 Introduction

The Mobile Ad hoc Network (MANET) is a collection of wireless mobile devices, where transferring data between them is done by intermediate devices independently from any base station. As it is mentioned in the Wikipedia about MANET, it is a self-configuring network of mobile hosts connected by wireless links with arbitrary topology where nodes randomly move and organize themselves arbitrarily; thus, the wireless topology network may change itself rapidly and unpredictably. Such a network could run individually; or it may be connected to the Internet [1]. Broadcasting scheme is a basic procedure used to send out information messages between mobile devices in MANET, and it's also the basic method for many protocols like Dynamic Source Router (DSR) [2] and AODV [3]. Although the broadcasting scheme is presumable to distribute messages between all nodes, it has several problems that decrease efficiency and performance in MANETs, such as, duplicate transmission, collisions and contention, these problems are called broadcast storm problem [4]. In many conventional on-demands routing protocol like AODV [3], a mobile host floods Rout Request control packets (RREQ) to its surrounding neighbors in order to discover a rout to explicit destination, then each neighbor rebroadcasts the RREQ control packets until the path between source and required destination is established. Recently, a probabilistic approach to flooding has been proposed to solve the broadcast storm problem, as one of most important suggested solutions [5, 6, 7, 15]. In the traditional probabilistic scheme, the mobile host will rebroadcast a broadcast message which is received for the first time with probability *p*. in this scheme; the rebroadcast decision is mad without any information about the network topology and the surrounding node neighbors.

This paper proposes new route discovery algorithms that called Smart Probabilistic Broadcasting (SPB), that enhance probabilistic broadcast methods to propagate the RREQ packets. To evaluate the SPB method we have used the AODV routing algorithm. Our results show that implementing AODV with SPB help to reduce the overall routing overhead with improved end-to-end delay when compare against the traditional AODV. The rest of the paper is organized as follow: Section 2 presents related work on some route discovery techniques. Section 3 provides a brief overview of on-demand route discovery process in AODV. Section 4 presents the effect of using different random way point models on the Number of neighbors. Section 5 presents Smart Probabilistic Broadcast mechanism (SPB). Section 5 shows the Performance Evaluation. Section 6 conducts Simulation Environment and

Scenario. Section 7 conducts a performance result of SPB. Finally, Section 8 concludes this study and outlines some directions of future research work

2 Related work

The direct method which uses broadcasting is flooding, where every mobile host receives a broadcast message and retransmits it to all nodes in network if it is received for the first time. In [4], the authors have studied different methods which directed to solve the broadcast storm problem, for example, blind flooding, probability-based, distance-based, counter-based, and location-based and neighbor knowledge schemes. In [7] Q. Zhang and Agrawal have implemented dynamic probabilistic broadcasting which combines the advantages of both counter-based and probabilistic methods. This algorithmic adjust the value of p based on the value of the packet counter, but it has drawbacks where the decision to rebroadcast is done after a random delay time and the probability decrease or increase according to small constant d which not explicitly specified . M. Bani Yassein et. al.[5,8], have proposed an improving on the probabilistic flooding by use multiple p, high, medium and low. These values set according to the local neighbors' information. This improving applied over the pure broadcasting, in term of *reachability* and *saved rebroadcast*. Qi.Zhang and Dharma have implemented approach that uses the concept of gossip and CDS. But the construct minimal dominating set is not required. Instead of that, categorizes mobile hosts into four groups according to their neighborhood information. For each group, there is a specified value of probability so the nodes with more neighbors are given higher probability, while the nodes with fewer neighbors are given lower probability [9]. Cartigny and Simplot [10] have proposed an algorithm which combine the advantages of both probabilistic and distance method to privilege the retransmission by nodes that are located at the radio border of the sender. The value of probability P is determined by the information collected form the nods neighbors and the constant value K which is efficiency parameters to achieve high reachability. In [11], the authors have proposed an adaptive counter based scheme in which each node dynamically adjusts its threshold value C based on local neighbors information. The fixed threshold C is computed based on a function $C(n)$, where n is the number of neighbors of the node. In this approach the value of n can be achieved through periodic exchange of 'HELLO' packets among mobile nodes.

In [12], the others have proposed an efficient broadcasting scheme that combines the advantages of pure probabilistic and counter-based schemes. The rebroadcast decision is depend on both fixed counter threshold and forwarding probability values. The value of probability is set according to packet counter which not exactly indicates the number of nods neighbors. Zone Routing Protocol (ZRP) [13] is another technique has been proposed to reduce RREQ control packets, which uses a combination of two protocols, *proactive* and *reactive;* it takes the advantages of both Protocols in order to solve the flooding of RREQ control packets. . In case of *proactive*, route information is available when it is needed; as a result, a node can immediately send a data packet to required destination in little delay prior to data transmission. But in case of *reactive*, because route formation is not available, a significant delay is produced in order to determine a route. The rout discovery procedure in ZRP is established as follow, if the destination inside the zone of the source which is called *Interzone Routing,* the source already knows the rout to destination, since the *Interzone Routing* uses proactive protocols. Otherwise, the source node will *bordercasting* RREQ control packets to its peripheral nodes instead of flooding it, since the path between nodes in different zones use reactive protocol.

In [14] the authors proposed a technique to reduce the RREQ overhead during route discovery operation, using the previous path. The authors suggest, when the path between source and destination is changed, the new path between them will not be extremely different than the previous one. In such case, the flooding operation for RREQ control packets will be done only by the new nodes in the new path at maximum k hops. The k hopes is a threshold calculated by the dissimilar between nodes form old and new path. However, this technique has disadvantages when is applied over a highly dynamic network.

3 Analysis the effect of using different system parameters on the number of neighbors.

In MANETs there are many important system parameters which have impact on network performance, like node mobility, nods density and traffic load; these are considered in the performance analysis [5]. Because the nodes in MANETs spread randomly and the topology changes frequently, the density of nodes will be different from low to high density. In this paper the forwarding probability p should consider this varying of density; since the probability p will set for different value in denser area (high density indicates p will be low), and also set for different value in sparser one (this means p will be high). The node's neighbor information is the simple approach to decide if current node in dense area or not, these information is collected by broadcast "Hello" packet every one second for only one-hop. This packet will guarantee for every node to have an updated neighbor list. By using the number of neighbors for each node the rebroadcast probability will dynamically adjusted, in order to trade off between the values of p and the node's surroundings environment. By extensive simulation study, three values of average numbers of neighbors are determined avg_1, avg and avg_2, which they are computed as follow. Let N is the number of nodes in the network; Ni is the number of neighbors for node X:

$$avg = \frac{\sum_{i=1}^{n} N_i}{n} \qquad \textbf{(4.1)}$$

The value of *avg* describes the average number of neighbors for all nodes in the network. It used as a threshold, since the node has neighbor above the *avg* it will be in a denser area, then the value of rebroadcast probability of p should set low, and if the node has neighbor below the *avg* that's mean the node in a sparser area, so the value of rebroadcast probability p is set high. This is a good indication to adjust the value of rebroadcast probability p for a given node according to its surrounding neighbors. However, this is not fair because all nodes that have neighbors below *avg* will rebroadcast for the same probability and also for the nodes that have neighbors above avg. Therefore, avg_1 and avg_2 are computed as follow, where K is the number of nodes that satisfy the condition:

$$avg_1 = \frac{\sum_{i=1}^{n} N_i}{k} \quad \textbf{where } N_i \leq avg, \qquad \textbf{(4.2)}$$

$$avg_2 = \frac{\sum_{i=1}^{n} N_i}{k} \quad \textbf{where } N_i > avg, \qquad \textbf{(4.2)}$$

Table 1 shows the summary of the avg_1, avg and avg_2 number of neighbors at a node for different nodes speeds. The results show that as the speed of nodes is increased, the avg_1, avg and avg_2 number of neighbors of the network also increases. This is because the node will visit different neighbors within a short slot of time. Table 2 shows the summary of the avg_1, avg and avg_2 number of neighbors at a node for different network densities. The results show that as the number of nodes increased, the avg_1, avg and avg_2 number of neighbors of the network also increases .This is because, as the number of nodes for a certain network is increased, the nodes will be close together. As a result, the number of neighbors for given node will increase.

Table 1: shows the values of avg_1, avg and avg_2 for different nodes speed.

Speed of Nodes	avg_1	avg	avg_2
4	3	12	21
8	5	13	26
12	7	15	28
16	10	20	31

Table 2: shows the values of avg_1, avg and avg_2 for different number of nodes.

# of Nodes	avg_1	avg	avg_2
25	4	10	16
50	8	20	32
75	13	30	49
100	18	39	63

4 Smart Probabilistic Broadcasting.

In the traditional AODV [3], all RREQ packets which have been received for the first time will flooded by the intermediate node. If the intermediate node dose not have a valid rout to destination, and N is the total nodes in the network, the number of possible broadcasts of an RREQ packet in AODV is N-2 (the source and destination will not retransmit a receive a RREQ that is being generated) [16]. A brief outline of the AODV-SPB in Fig.1.On hearing a broadcast RREQ packet at node X for the first time, the node compared its neighbor by avg_1, avg and avg_2, if the node has number of neighbor n less than avg_1, this implies that the node is in a low sparse region, the node rebroadcasts the packet according to probability p_1. However, the probability p_2 is selected if the number of neighbors n are such that $avg_2 \leq n < avg$, this implies that the node is in a medium sparse region. The value of probability p_3 is chosen if the node is a medium density region and the number of neighbors n are such that $avg \leq n < avg_2$. Finally, the value of probability p_4 is chosen if the numbers of neighbor's n are such that $n \geq avg_2$, this implies that the node is in a high density region. The values of p_1, p_2 , p_3 and p_4, respectively, will be $p_1 > p_1, > p_1, > p_1$.

The Smart Probabilistic Broadcasting ():

Get the number of neighbor n for the node X that receives RREQ.
Get the values of avg_1, avg and avg_2.

If packet RREQ received for the first time **then**
  If $n < avg_1$ **then**
  Node X *is* located in Low sparse region: $P= p_1$;
  Else if $avg_1 \leq n < avg$ **then**
  Node X *is* located in medium sparse region: $P= p_2$**;**
  Else if $avg < n \leq avg_2$ **then**
  Node X *is* located in medium dense region: $P= p_3$**;**
  Else if $n \geq avg_2$ **then**
  Node X *is* located in high dense region: $P= p_{4;}$
    End_if
  End_if
  Generate a random number RN over [0, 1].
  If $RN \leq P$ **then**
    Rebroadcast the received RREQ.
  Else
    Drop it.

End_algorithm

Figure 1: Description of the algorithm.

5 Performance evaluation

The traditional AODV protocol which use blind flooding during rout discovery, has been modified by replaced the blind flooding with new adjusted probabilistic scheme. AODV is already implemented in NS-2 packet level simulator [17]. The aim is to reduce the flooding of RREQ packets during the rout discovery operation, and as a result reduces the broadcast storm problem. The net effect is that overall network improved by reduced the average end-to-end delay and also routing overhead. Since the decisions of the nodes are independent, the total number of possible rebroadcasts of an RREQ packet, N_b [16], using the SPB algorithms is :

$$N_b = \sum_{i=1}^{4} p_i N_i \quad \textbf{for the SPB-AODV,} \qquad \textbf{(4.3)}$$

Where N_i is the number of nodes that chose p_i. If N is the total number of nodes in the network then, the total number of rebroadcasts of an RREQ packet in SPB-AODV, AODV-FP and AODV-BF are respectively related as follows [16]:

$$\sum_{i=1}^{4} p_i N_i < p \times (N-2) < N-2 \qquad \textbf{(4.4)}$$

The value of fixed probability that used in AODV-FP is set at *p*= 0.7. [5, 6] has shown that this probability value enable fixed probabilistic flooding to achieve a good performance.

6 Simulation environment

Ns-2 is used as the simulation platform. Ns-2 is a discrete event simulator, it is designed by researcher at Berkeley University and targeted at networking research, Ns-2 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless networks. The simulation scenarios consist of different mobile nodes moving in different network area; each node has 250 meter transmission range and having bandwidth of 2Mbps. Each data point in the simulation results represents an average of 30 randomly generated mobility patterns in order to achieve a 95% confidence interval in the collected statistics. The MAC layer protocol is IEEE 802.11.The nodes move according to the random waypoint model. This mobility model is used to simulate 30 topologies. The speed varies 2 to 16 m/sec and pause time 0 sec. The main parameters used in the simulations are summarized in Table 3.

Table3: Summery of the parameters used in the simulation experiments

Parameter	Value
Transmitter range	250
Bandwidth	2Mbit
Interface queue length	50 messages
Simulation time	900 sec
Packet size	512 bytes
Topology size	$500 \times 500\ m^2$
Nodes speed	2,4,8,12,16 m/sec
Pause time	0,10,40,80,120 sec
Number of node	25,50,75,100 nodes
Traffic load	5,10,20,30 connections
Data traffic	CBR
Mobility model	Random Way-Point
Number of trials	30 trial

7 Effect of network density

Fig.2 shows the performance of the three protocols in terms of routing overhead versus network density. The RREQ Packets increased as the number of nodes is increase. The routing overhead generated by AODV-SPB is lower compared by AODV-FB and AODV-BF. Fig.3 demonstrates the effects of network density on the performance of all the three protocols in terms of normalized routing load. The AODV-SPB has superior performance over AODV-BF and AODV-FP. For example, at high network density (e.g. 100 nodes) the normalized routing loads for three protocols: AODV-SBP, AODV-FB and AODV-BF are reduced by about 0.5, 0.7 and 0.9, respectively. Fig.4 reveals that the delays incurred by all the three protocols. When network density increase, the number of duplicated RREQ packets which generated by nodes is also increased, and this is icreased the number of droped packets. As a result, , packets experience high latencies in the interface queues.

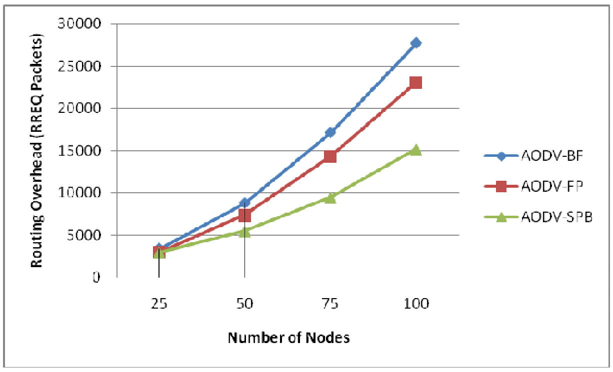

Figure 2: Routing Overhead vs. Number of Nodes placed over 500x500.

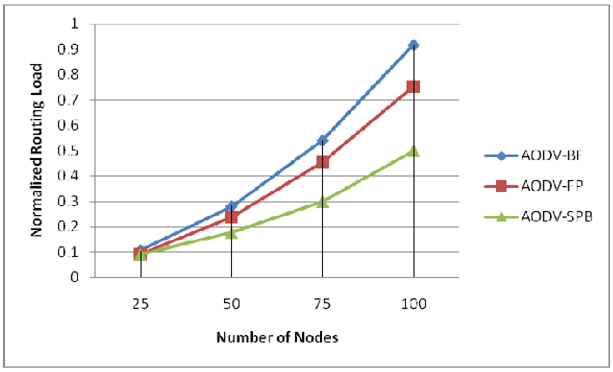

Figure 3: Normalized Routing Load vs. Number of Nodes placed over 500x500.

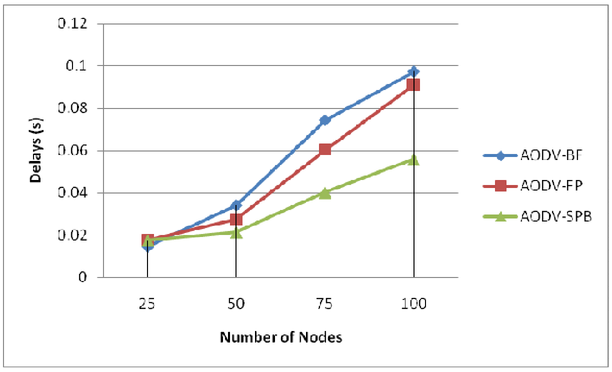

Figure 4: delay vs. Number of Nodes placed over 500x500.

8 Effect of network mobility

Fig.5 shows the routing overhead of AODV-SPB, AODV-FP and AODV-BF with different mobility scenarios when the number of CBR is set at 10. When node mobility increased, more RREQ packets fail to reach their destinations. In such circumstances more RREQ packets are generated and retransmitted, which lead to higher chance of collision due to the increase in control packets. For instance, the AODV-SPB performs better than AODV-FB and AODV-BF by reducing the overhead form around 14000, 21000 and 26000, respectively. Fig.6 shows the network normalized routing load achieved by the three routing protocols against the maximum node speed. The figure shows that the network normalized routing load achieved by the protocols increased with increased node mobility. This is due to the rout between any pair of source and destination will frequently change when the speed of nodes increased, which lead to increase the number of retransmitted RREQ packets. The AODV-SPB has a higher performance over AODV-FB and AODV-BF.

The fig.7 depict the end-to-end delay of data packets in three routing protocols for different nodes speed. The figure shows when nodes speed increase the end-to-end delay of data packets is increased. This is because the pathes between sourses and requried destinations frequently changed and established. As a result, the wating time for data packets in interface queue is increased. However, among all maximum node speeds the AODV-SPB performs better, followed AODV-FP and AODV-BF. For instance, at the node speed 16m/sec, the delay is around 0.049, 0.033 and 0.031 for AODV-BF, AODV-FP and AODV-SPB, respecively.

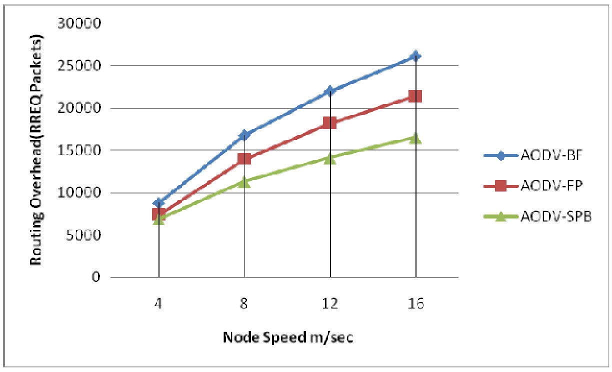

Figure 5: Routing Overhead vs. node speed for a networksize of 50 node and 10 connections.

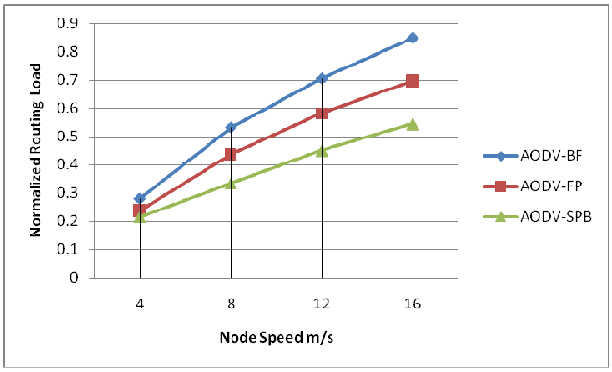

Figure 6: Normalized routing load vs. node speed for a network size of 50 node and 10 connections.

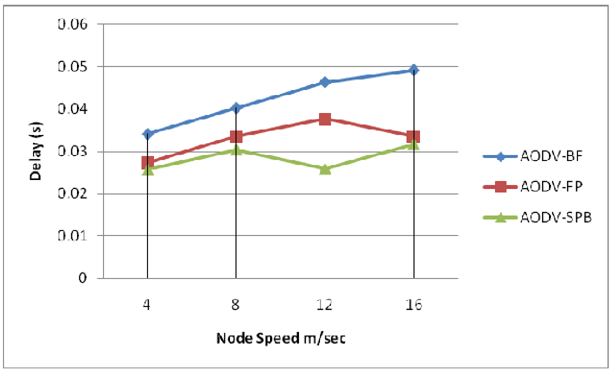

Figure 7: Delay vs. node speed for a network size of 50 node and 10 connections.

9 Effect of offerd traffic load

The results depicted in Fig. 8 show the routing overhead generated by all the three protocols when the offered load is increased from 5 to 30 flows. As revealed by the Fig.12, AODV incurs a lower routing overhead compared to AODV-BF and AODV-FP. For instance, at a heavy traffic load (e.g. 30 connections) the generated overhead is reduced by around 15000 and 5000 when used AODV-SPB and AODV-FB, respectively. The results in Fig. 9 show that the normalized routing load for three routing protocols, when the traffic load increased form 5 to 30 flow. The results in Figure reveal that AODV-SPB has a clear performance over AODV-FP and AODV-BF. For instance, compared with the AODV-BF and AODV-FP, the results shows that at high traffic (e.g. 30 connections), the normalized routing load is reduced when used AODV-SPB by around 0.4 and 0.2, respectively.

Fig.10 shows the that the delays incurred by all three protocols for different traffic loads. The number of total packets transmitted on the wireless channel has a significant impact on latency. If the number of packets is high, then the number of collision is high, and in turn lead to more retransmissions. As a result, packets experience high latencies. The data packets in AODV-SPB experience a lower latency than in AODV-FP and AODV-BF. This is because that there a higher number of redundant rebroadcasts of RREQ packets. This is leading to channel contention, packet collision and as a result many RREQ packets fail to reach the destinations.

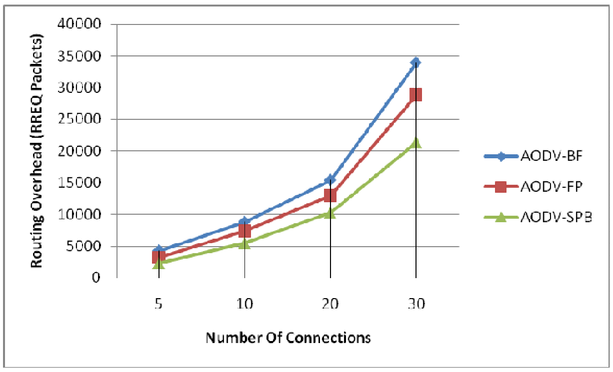

Figure 8: Routing overhead vs. traffic for a network size of 50 nodes and with node speed 2 m/sec.

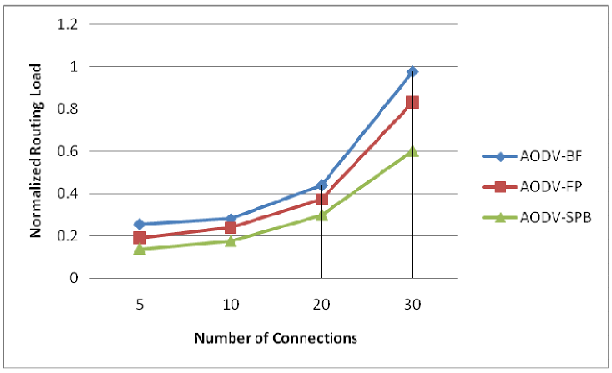

Figure 9: Normalized Routing Load vs. traffic for a network size of 50 nodes and with node speed 2 m/sec.

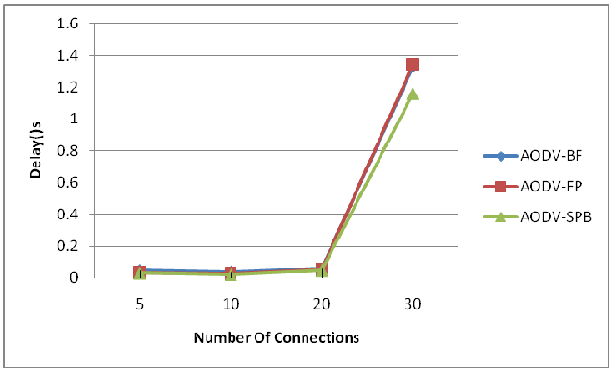

Figure 10: Delay vs. traffic for a network size of 50 nodes and with node speed 2 m/sec.

Effect of network pause time load

The results depicted in Fig. 11 show the routing overhead generated by the five protocols when the pause time of nodes is increased from 10 to 120 s. As it is revealed by the Fig.11, AODV-SPB with one, two and three *p*, incur a lower routing overhead compared to AODV-BF and AODV-FP. For instance, when the network pause time is 120, the generated overhead is reduced form 25000 and 22000 when using AODV-HASP Band AODV-BF, respectively.
The results depicted in Fig. 12 show the normalized routing load generated by all five routing protocols with different network pause time, and the number of CBR is set at 10. When the networke pause time is increased, the mobility of nodes is decreased, and the pathe between source and destination will not need a lot of RREQ pakcets. This leads to decrease the normlaized routing load. The results in Figure reveal that AODV-HASPB, AODV-ASPB, AODV-SPB have a better performance over AODV-FP and AODV-BF. Fig.13 shows the that the delays incurred by all five protocols for different network pause time. The longer the average pause time is the less the node movement within the network, this means that the nodes look like fixed rather than mobile, so the number of generated RREQ packets will be low at network with high pause time.

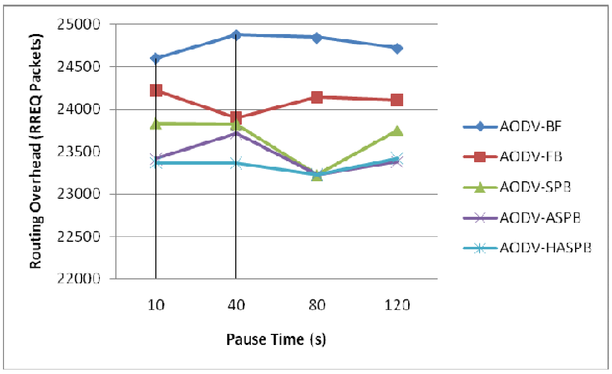

Figure 11: Routing overhead vs. network pause time for a network size of 50 nodes and with node speed 2 m/sec.

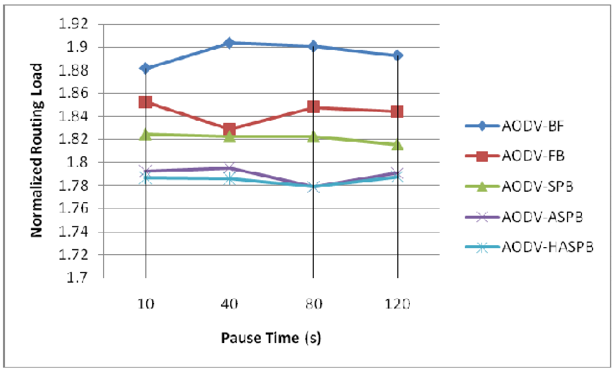

Figure 12: Normalized Routing Load vs. traffic for a network size of 50 nodes and with node speed 2 m/sec.

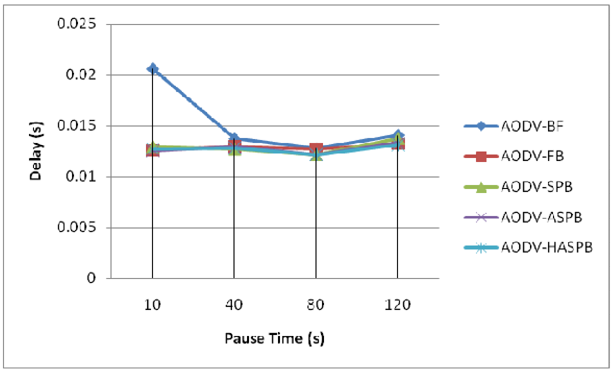

Figure 13: Delay vs. traffic for a network size of 50 nodes and with node speed 2 m/sec.

10 Conclusions and Future works

In this paper, the simulation results show that new Smart probabilistic blind flooding algorithm AODV-SPB has superior performance over than traditional AODV-BF and AODV-FP. The AODV-SPB generates much lower routing overhead and end-to-end delay, as a consequence, the packet collisions and contention in the network is reduced. The results have also shown that although the traffic load increased, the normalized routing load is still low.As a continuation of this research in the future, we plan to combine the AODV-SPB with different approach which suggested to solve the broadcast storm problem, and analysis the effect of this improvement on the performance of DSR.

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