A New Adaptive Broadcasting Approach for Mobile Ad hoc Networks

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Abstract—*Mobile ad hoc networks (MANETs) have been gaining tremendous attention owing to the advances in wireless technologies accompanied by many applications and implementations. However, there are still a number of issues in MANETs which require further investigations and efficient solutions. Out of these issues, broadcasting in MANETs has been a major problem for both industry and the research community. The broadcast communication is usually required to disseminate a message to all the nodes of a network. This operation is highly required in MANETs to distribute necessary information and ensure efficient control and coordination over the network nodes. However, broadcasting in MANETs is usually susceptible to several challenging communication issues, including, flooding, packets contentions and collisions, i.e., these problems all together are called the Broadcast Storm Problem (BSP). Despite a number of suggested solutions for BSP, the probabilistic scheme is considered the most promising solution due to its simplicity and suitability for MANETs. Under the umbrella of this scheme, many dynamic probabilistic broadcasting algorithms have been proposed in the literature to solve the BSP. However, most of them are not suitable for many applications including those real life scenarios as there are many limitations such as the probability of rebroadcasting operation and thresholds rebroadcasting permission, which is caused by collecting local neighbourhoods' connectivity by broadcasting HELLO packets. In an attempt to enhance and promote the quality of the probabilistic scheme, this paper proposes a new probabilistic approach to overcome these limitations. Our proposed approach is augmented with a well-know ad hoc routing protocols including Ad hoc On demand Distance Victor protocol (AODV). We have conducted intensive simulation experiments under different operating condition. The simulation results show that our proposed approach outperforms its counterparts including the well known blind flooding, fixed probabilistic and traditional dynamic probabilistic approaches.*

Index Terms—*Broadcast, Flooding, Probabilistic, RREQ, Simulation and AODV.*

1. INTRODUCTION

Wireless networks can be divided into two types, single-hop and ad-hoc multi-hop networks. The first type is the single-hop network where the communication between nodes accomplished based on a fixed structure (i.e. base stations, access points and servers are deployed before the network can be used).The second type is Mobile Ad-hoc Network where the communication between nodes is accomplished via other nodes which are called intermediate or forwarded nodes. The nodes in Ad hoc networks are dynamically formed with no need for an existing infrastructure or pre-configuration, such as, base station or access point. MANETs can be deployed and operated without depending on a fixed backbone. So it is considered very useful for many applications, for example, military operations, emergency and applications that run for a limited time period. In this paper we investigate our contribution based on ad hoc multi-hop networks.

The broadcast concept refers to the sending of a message to other hosts in the network, and it has two characteristics [1]. Firstly, broadcast is spontaneous, since a given node can broadcast any message at any time; this is due to the nodes' mobility and the absence of synchronized mechanisms in MANETs. Secondly, because there is no acknowledgement mechanism used between mobile nodes, the sender will not be able to detect or retransmit the dropped packets, of what make the broadcast is unreliable.

The nodes in the MANET may dynamically and randomly communicate with each another. To send a message from one node to another node in a network, many intermediate nodes relay this message because the required node might not be within the transmission range of the source node; this scenario is called Multihopping [2]. There are two types of broadcasting models that can be used to transmit a message, the one-to-all model and the one-to-one model [3]. In the one-to-all model, transmission message must be sent to all nodes that are within its transmission radius of source node, while in the one-to-one model, each transmission is sent to only one neighbour "via a narrow beam directional antenna or separate frequencies for each node" [3,4]. Our proposed solutions have been examined based on one-to-all model. An example of this model is the broadcasting of RREQ packets and HELLO messages in some routing protocols [5, 6]. Broadcasting is also used in many important applications such as alarms and announcements, for services discovery and advertisement in vehicular ad hoc networks [7], and consistency update propagation [8].

In ad hoc routing protocols, broadcasting is considered as a basic procedure to diffuse a message from source node through intermediate nodes to destination node. Such a procedure includes; route discovery, paging a particular node, address resolution, and many other network services in a number of routing protocols [3, 4]. For example, AODV, dynamic source routing (DSR), and location aided routing (LAR) [9], use broadcasting operations to discover a route to

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a required destination. These protocols perform the broadcasting by a simple form so-called flooding, in which each mobile host rebroadcasts any received packet for the first time to all hosts. Although flooding technique can success to achieve high messages that reach all nodes in the network, it simply swamps the network with excessive redundant number of rebroadcast messages, which leads to the BSP [1].

Nodes in MANETs move randomly and also they can arbitrary connect to the network or disconnect from it. So, the operation of establishing routes between any pair of nodes within an ad hoc network can be difficult, because the randomly movement of nodes and they can also arbitrary join and leave the network. This means that an optimal route at a certain time may does not work again. Classification of routing protocols in MANETs can be done in three methods depending on routing strategy; proactive, reactive and hybrid.

Proactive protocols, also known as table driven protocols such as Destination-Sequenced Distance-Vector Routing (DSDV) [10] and Optimized Link State Routing Protocol (OLSR) [11] have been widely studied. This type of protocols attempt continuously to keep a table for each node containing all the routes within a network independently of traffic demands. On the other hand, reactive protocols, also known as on-demand routing protocols such as AODV and DSR establish routes between nodes only when a node requires sending data packets to another node in the network. There is no need to update all routes in the network; instead it focuses on routes that are being used or being set up. Hybrid protocols combine the advantages of both reactive and proactive protocols, such as Zone Routing Protocol (ZRP) [12, 13]. The hybrid protocols use on-demand protocol to establish a route to destination networks, and use reactive protocol to update routing table information at each node only when the topology of the network is changed.

Many researchers have demonstrated that a probabilistic scheme is the simple and straightforward solution to handle the BSP. Therefore, there are a lot of probabilistic broadcasting methods that have been proposed as a solution to enhance the MANETs performance by mitigating the effect of using broadcasting operation [14-17]. Although these methods have superior performance in reducing the BSP, most of them have shortcomings in developing solutions to set the value of retransmission probability automatically instead of setting it manually in advance. This makes such algorithms not applicable in MANETs real life applications. Furthermore, these algorithms use HELLO packets to collect a local 1-hope neighbourhood's information and classify whether a current region is dense or sparse, then making a broadcasting decision based on region density. Consequently, this introduces a new problem since HELLO packets do not provide accurate indication about number of neighbours for each node. It would be more desirable if the probabilistic algorithm took into account global information about the number of neighbours rather than just use a local method such as using HELLO packets. Our adaptive approachwork proposes a new algorithm to handle the weakness of existing probabilistic schemes. We incorporate these algorithms with AODV and evaluate its performance by using NS-2.34.

The rest of the paper is organised as follows. Section 2 introduces related work on some solutions that were suggested to handle the BSP. Section 3 describes some important functions of AODV. Section 4 presents a detailed description of our algorithm and its component. Section 5 provides an extensive performance evaluation of our algorithm. Finally, section 6 concludes the paper and outlines our future work. .

2. RELATED WORK

Flooding technique is considered as a simple and direct approach to broadcast a message from one node to another node in the network. Many ad hoc routing protocols use flooding to insure that all nodes receive the source message, since the reachability of this approach is approximately up to 100% [15, 16]. However, the drawbacks of using flooding, that leads to BSP, is that it is unsuitable for MANETs. Thus, the researchers [1,14-20] debate that performing broadcasting operation without depending on the flooding technique can minimize the BSP and improve the MANETs performance in terms of low collision, overhead and end-to-end delay. Below is a brief description about some of recent techniques that have been used instead of flooding.

A fixed probabilistic scheme is the first probabilistic approach and considered as the base for all later dynamic probabilistic schemes. In which every node receives a broadcast message for the first time, rebroadcasts it to all nodes in the network with a certain value of probability P, regardless of the density level of current node. The researcher in [1] has shown that, the best value of P in terms of high reachability and saved rebroadcast is approximately equal to 0.07%.

In our earlier approach [18] we have demonstrated that if the probabilistic scheme considers the degree of nodes density, it will outperform the fixed probabilistic scheme. Therefore, we have developed a smart probabilistic broadcasting algorithm which divides the MANET into four levels of density; sparse, medium sparse, dense and high dense, and assigns a specific forward value of P for each level. The density information is collected by broadcasting HELLO packets every second for 1-hop to construct a neighbour list at each node. Then, the node can decide in which four levels currently it is by comparing its neighbour list with average network neighbours. This scheme opens up a promising approach towards optimal probabilistic broadcasting. In this paper we have implemented such approach work and approved its optimality compared with other probabilistic schemes.

In the counter-based scheme, every node has a counter C to store a number of received messages. The node will rebroadcast the message when C has a value less than pre-defined threshold within a period of Random Assessment Delay (RAD) time. However, this scheme is not suitable for applications that have a very high speed movement like

Vehicular Ad hoc Networks VANETs. A recent approach that combines the advantages of using counter and probabilistic scheme has been proposed to solve the BSP in MANETs based on realistic mobility model [19].

In the distance-based scheme, when the distance between two hosts is very small (less than a threshold), the broadcast message will not be rebroadcasted, since the additional coverage will be very small. If the distance exceeds a certain threshold, the packet can be rebroadcasted because the additional coverage will be significant. On the other hand, in the locations-based scheme, when a host receives a broadcast message for the first time, the additional coverage provided by the host will be initialized and compared with a predefined coverage threshold in order to decide the broadcast operation. This scheme needs to use GPS (Global Positions System) to find the hosts' locations. Nevertheless, the power consumption along the cost of using GPS are considered a critical issue in wireless network [1, 19].

Many reasons have thus motivated the researchers to choose a probabilistic scheme out of all schemes as it is the most appropriate solution to solve BSP [1, 14-18]. First, it is easy to implement because it needs a few lines of code to design it. Second, there is no need for additional hardware to operate it for example GPS. Finally, the mobile nodes can rebroadcast immediately with no need to wait a random delay time such as RAD in counter based scheme, which makes it suitable for high mobility applications.

3. AODV OPERATION

AODV is one of the most important reactive routing protocols and it is widely used in MANETs. This type of protocols establishes routes between nodes only on-demand (when they are required to send data packet). There is no need to update all routes in the network; instead it focuses only on routes that are currently used or being set up. Below is a description of the two important functions in AODV.

3.1. ROUTE DISCOVERY OPERATION

Any mobile host can broadcast a RREQ packet when it needs to send information to another mobile host in the network and does not have a valid path to it. Intermediate nodes rebroadcast the received RREQ for the first time to all hosts in the network. This process only stops if the required destination is found and the successful path established. The total cost of using broadcasting technique to find a path between pairs of nodes is equal to the number of nodes in the network, but the source and destination are excluded. This is because the source does not rebroadcast its packet and the destination sends back a Route Replay packet when it is reached.

3.2. NETWORK CONNECTIVITY METHOD

Maintaining local network connectivity can be done either by broadcasting local HELLO packets or through network layer mechanisms. A node sends HELLO packet every second for 1-hope to insure that weather it has a valid route to its neighbours or to create one if necessary. If the node already has a valid route, then the Lifetime variable should be increased for a current route to be at least equal to HELLO INTERVAL* ALLOWED HELLO LOSS. HELLO INTERVAL is used as a threshold time waiting to set the maximum number of seconds of waiting for the node before sending another hello message to its neighbours. ALLOWED HELLO LOSS is used to determine neighbours node connectivity. If the node does not receive a HELLO packet with the maximum number of periods of HELLO INTERVAL the node will assume it has lost its neighbours connectivity. The author in [6] has recommended value for HELLO INTERVAL is one second and for ALLOWED HELLO LOSS is two seconds.

The network layer can maintain the local connectivity by those mechanisms that provided by IEEE 802.11 such as RTS/CTS (Request to Send / Clear to Send). When a node fails to receive CTS after sending RTS, this indicates that the connectivity between nodes is currently not available.

4. ADAPTIVE BROADCASTING APPROACH

In this section we present the Adaptive Broadcasting Scheme (ABS) that aims to handle the BSP as a result of using a flooding technique during the route discovery operation in AODV. The main finding of using such the approach is to find an effective solution represented in (1) adjusting the forwarding probability P based on the global and local neighbourhood information, (2) setting the value of probability during the run time code generation rather than during the design time to make it more realistic, and (3) reducing dependency on using thresholds to determine the degree level of density for a given node.

A brief outline about ABS is represented in Figure 2 and operates as follows. When a node x receives a RREQ packet for the first time, it first calculates the number of neighbours $N_{HELLO\_PACKETS}$ by broadcasting HELLO packets for 1-hope to collect local information about the surrounding neighbours. Similarly, the node x calculates the number of neighbours $N_{Transmission\_Range}$ within its transmission range to collect global information about the surrounding node environment. Our experiments show that collecting neighbourhood information by using 1-hope HELLO packet does not give a complete view to decide whether the current node is located in dense or sparse area compared by $N_{Transmission\_Range}$ which provides general and more precise information about nodes' density. For example, when a number of nodes in the network are equal 100 and the transmission range is 250 m, the average values of the neighbours with $N_{Transmission\_Range}$ = 55 and $N_{HELLO\_PACKETS}$ = 25. This means that the node is considered located in a sparse area according to $N_{HELLO\_PACKETS}$ value while it is actually located in a dense area according to $N_{Transmission\_Range}$ value. Figure 3 depicts the main difference between the above two methods.

Let A be the area for a give ad hoc network, and R the signal node transmission range; let α be the fraction of the total network area covered by a mobile node R. The total number of neighbours that can be covered by R is represented as follows:

$$\alpha = \frac{\pi R^2}{A} \quad (1)$$

In order to determine if the node J is neighbour for the node I we used the *IsNeighbor(J,I*) function which already implemented in NS-2.34. This function can decide if the node I is inside node J by comparing the desistance between these two nodes with transmission range of node J. For example, if the transmission range for node j is 250 m and the distance between node J and I is equal 200 m, the node I is considered the node's J neighbour.

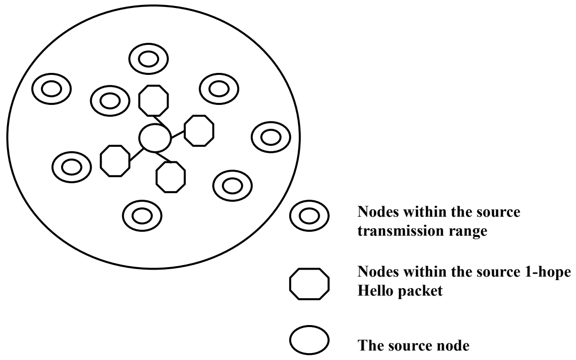

Fig.2. Logical description of the proposed solution.

Adaptive Broadcasting Scheme

Begin

{

Step1: Upon reception of a broadcast RREQ at a Node *X* for the first time.

Step2: Get the Number of neighbours for 1-hope $\boldsymbol{N_{Hello\_Packet}}$ // *local neighbourhood information.*

Step3: Get the Number of neighbours within node's transmission range $\boldsymbol{T_{ransmission\_Range}}$ // *global neighbourhood information.*

Step3: Set the value of rebroadcasting probability according to local and global density:

P = $\boldsymbol{N_{Hello\_Packet}} / \boldsymbol{T_{ransmission\_Range}}$.

Step4: Generate a random uniform number R over the interval between [0,1]{

If (R > P)

Rebroadcast the received RREQ packet

Else

Free(RREQ)

}

}

End

Figure 1: Description of the algorithm.

The rebroadcast probability should be set differently for one node to another in order to alleviate the number of rebroadcasting RREQ control packets and increase the efficiency of the network. To verify this condition an inverse relationship should be derived between the number of neighbours and the value of P. Therefore, the ratio of the number of neighbours within the nodes transmission range and 1-hope neighbours is suggested to determine the degree density percentage for the rebroadcasting node. For the above same example, the value of $N_{HELLO\_PACKETS}$ / $N_{Transmission\_Range}$ represents the density level of node and the value of P, which equal in this example to 0.45, at the same time.

Upon the selection of the value of forwarding P, the algorithm generates a random number between the interval [0, 1], compares it with the value of P, and decides to rebroadcast or drop the RREQ packet

5. PERFORMANCE ANALYSIS

To evaluate the performance of the new ABS, we used NS-2.34 as the simulation platform designed by researchers at Berkeley University. NS-2.34 provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless networks. Two different network settings and conditions have been considered for this study, each designed to evaluate the performance of the proposed protocols over a wide range of different ad hoc networks parameters. First, the impact of network density is assessed by deploying a different number of mobile nodes over a topology of 1000m x 1000m. Second, the effects of an offered load on the performance of the broadcast schemes have been investigated by changing the number flow for each simulation experiment. We have varied the nodes density from low to high, and the traffic load as well from low to high to insure that our approach is applicable over different network densities and traffic loads.

We present the performance results of our scheme ABS against those for Fixed Probability (FP-AODV), Blind Flooding (BF-AODV) and Smart Probabilistic Broadcasting (SPB-AODV) [18]. Each collected data point in the simulation output represents an average of 30 different randomly generated mobility models with 95% confidence intervals. The average of 30 randomly network topologies give more precise and accurate results than, for example, 10 or 20 topologies. The main parameters used in the simulations are summarized in Table 1.

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

•**Routing overhead:** The total number of RREQ packets generated and transmitted during the total simulation time.

•**Collisions rate:** The total number of RREQ packets dropped by the MAC layer as a result of collisions between RREQ packets during route discovery operation, per simulation time unit.

•**End-to-end delay:** The average delay that a data packet takes to reach from source to destination. This includes all possible delays caused for example buffering during route discovery delay and queuing at the interface.

5.1. IMPACT OF NETWORK DENSITY

The network density has been varied from low to high density by changing the number of nodes placed in a 1000m x 1000m area of each simulation scenario. Each node moves according to a random way point mobility model [21] with a speed chosen between 1 and 4m/sec to mimic the human speed in this scenario. For each simulation experiment, the number of random source and destination connections are selected to be 10 (i.e. traffic flows), each generates 4 data packets/second.

- *Collisions Rate*

Figure 3 shows that the number of packets collisions incurred by the four protocols increase as the number of nodes grows. The scalability and applicability characteristic of ABS-AODV becomes obvious when the number of nodes increases. This is due to the reduction of the possibility of having more than two nodes transmitting at the same slot time by using ABS-AODV. As a result a number of large duplicated and dropped packets are reduced. For instance, Figure 4 depicts that the collision rate of ABS-AODV is reduced by approximately 50% 40% and 30% against BF-AODV, FB-AODV and SPB-AODV.

- *Routing Overhead*

Figure 4 shows the routing overhead incurred by ABS-AODV, SBP-AODV, FB-AODV and BF-AODV for different network densities. The figure shows that for a given network density, the generated routing overhead incurred in each of the four routing protocols increases proportional to the number of nodes. In fact, we can conclude that there is a direct relationship between the number of nodes in the network, and the number of RREQ packets. However, the ABS-AODV outperforms all the other protocols. For example, the routing overhead in ABS-AODV is reduced by approximately 52% for the 100 nodes network compared with BF-AODV.

5.1. IMPACT OF OFFERED TRAFFIC LOAD

In this section, we investigate the impact of traffic load with the injection rates of 5, 10, 20, 30 and 40 packets per second. The network topology is 1000m x1000m, and 100 nodes are deployed over it. Each node in the network moves according to random way point mobility model with speeds chosen between 1m/s and 4m/s respectively.

- *Collision Rate*

The results in Figure 5 show that the number of collisions incurred by the routing protocols increase as the offered load increases. This is because; as the offered load increases the number of RREQ generated and disseminated packets increases too. Thus, many RREQ packets collide with each other due to self contention between nodes in the same shared transmission channel in the network. The figure also reveals that for a given injection rate point, ABS-AODV outperforms SPB-AODV FB-AODV and BF-AODV. For instance, the collision rate of ABS-AODV is approximately 49% lower than that of BF-AODV.

- *Routing Overhead*

Figure 6 depicts that the routing overhead generated by the routing protocols increases with increased offered load. This is because; as the number of flows increase the number of pairs between sources and destinations increase. To open any connection between any two nodes, the RREQ packet should be initiated and broadcasted. As a result, more RREQ control packets generated and broadcasted. For instance, when the number of connections increases from 5 to 40, the routing overhead generated by ABS-AODV, SPB-AODV and FP-AODV is reduced by approximately 49%, 45% and 25% respectively.

Table1: 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
Pause time	0 sec
Packet size	512 bytes
Topology size	$1000\times1000\ m^2$
Nodes speed	4 m/sec
Number of node	25,50,75,100 nodes
Traffic load	5,10,20,30
Data traffic	CBR
Mobility model	Random Way-Point
Number of trials	30 trials
	31

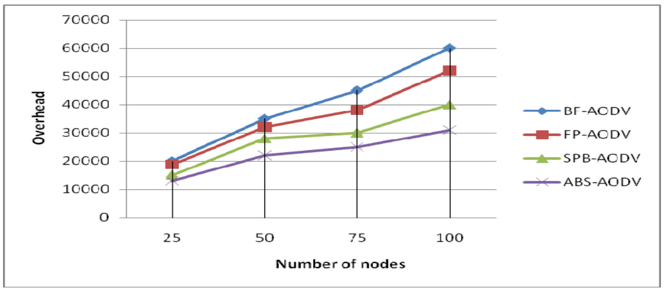

Fig.3. The impact of network density on the Overhead.

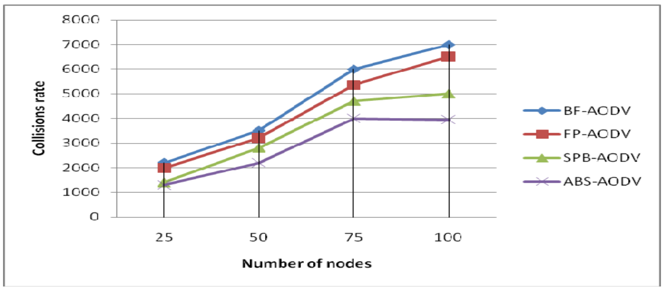

Fig.4. The impact of network density on the collisions rate.

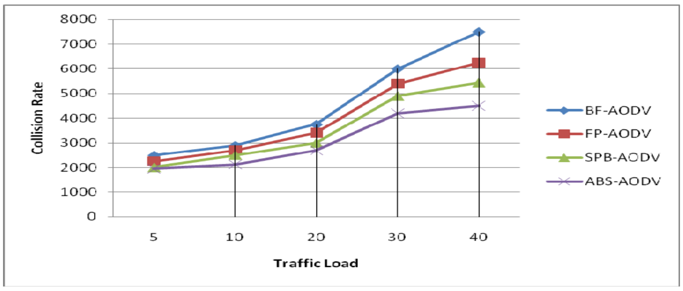

Fig.5. The impact of traffic load on the collisions rate.

6. CONCLUSION AND FUTURE WORK

In this paper, we proposed a novel solution for the broadcast storm problem in MANETs. Our proposed approach is based on the well known probabilistic scheme. We have conducted simulations experiments and evaluated our proposed scheme under different operating conditions including different network densities and offered loads. We showed that our approach can significantly improve the broadcast operation in MANETs due to our new efficient adaptation mechanism. Moreover, it is also confirmed that our approach outperforms existing protocols by reducing network overhead and packets collision. As a future work, we can deploy our approach in more scenarios and large scale networks. We anticipate that our adaptive approach will help us to better deploy broadcast, provision, control, and support the MANETs than existing solutions under different operating conditions.

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