A New Efficient Distributed Route Discovery for Wireless Mobile Ad hoc Networks

Mustafa Bani Khalaf, Ahmed Y. Al-Dubai ,William Buchanan
School of Computing, Edinburgh Napier University
10 Colinton Road, Edinburgh, EH10 5DT, U.K.
E-mail :{m.banikhalaf, a.al-dubai, w.buchanan}@napier.ac.uk

Abstract- **High performance group communication, such as broadcast, requires matching efficient broadcast algorithms to effective route discovery approach. Broadcast communication in MANETs is essential for a wide range of important applications. Nevertheless, existing broadcast schemes in MANETs suffer in terms of several issues such as rebroadcast redundancy and collisions. Consequently, this degrades the communication quality especially when dealing with high bandwidth applications. Thus, this paper adopts a new strategy that presents a new distributed route discovery (DRD) scheme to handle the broadcast operation efficiently by reducing the number of the broadcast redundancy request (RREQ) packets and the number of collision and contentions. We examined the performance of the proposed scheme DRD in MANETs; in terms of RREQ rebroadcast number and RREQ collision number. Our experiments confirm the superiority of the proposed scheme over its counterparts in different communication constraints.**

Kew-Words: Broadcast, Probabilistic route discovery and Network global and local Density.

I. INTRODUCTION

Mobile ad-hoc networking (MANET) technology has been a major avenue for many wireless and mobile networked based applications in different fields including, but not limited to, industry, military, and public services including the emerging ones such as the intelligent transport systems (ITS) that aim to enhance the road safety [1]. In ITS, MANETs are used to disseminating a warning messages between cars on the roads about road accidents, emerging regulations or weather related information. In addition MANETs can be used effectively in rescue management operations in urban and rural areas [2]. The self configuration, self healing, the non-infrastructure nature, high mobility, ease of implementation and cost-effective operation are among the major desirable characteristics of this networking technology.

Indeed, the *broadcast communication* (or one-to-all communication) is one of the most primitive collective capabilities of any network. It is also central to many important group-based applications, and fundamental to the implementation of other group communication-based operations. Furthermore, broadcast is widely used to send information messages between nodes in many applications such as real-time applications including online TV, distance learning and gaming and so forth. Evidently, broadcast reduces the cost of communication compared to sending unicast packets multiple times. For instance, broadcasting warning messages between cars on the roads about road accidents or weather information. Route discovery is a cornerstone operation in many ad hoc routing protocols that uses [3] [4] broadcast to setup a route between the source and its destination(s). One of the primitive and widely deployed methods of implementing the broadcast is Simple Flooding (SF) [5]. In this approach, each node 'floods' the network, with the message that has received, in order to guarantee that other nodes in the network has been successfully reached.

Although flooding is a simple and reliable; however, it consumes a great deal of network resources, since it swamps the network with high redundant packets, leading to collisions,contention and huge competition while accessing the same shared wireless medium. This phenomenon is well known in MANETs and so-called *Broadcast Storm Problem* (BSP) [5]. Apparently, most existing proposed broadcast schemes focus on mitigating the broadcast associated problems by restricting the discussion to the BSP problem in dense MANETs topologies. In contrast, in this paper we address the *disconnected network* problem (in addition to the broadcast storm), which appears when no relay node within the sender transmission range can forward the packet to other nodes. Recent proposed schemes [6] [7] [8], suffer from the *simultaneous broadcast* problem, since a fixed timer is used at all nodes without considering the level/degree of network density; thus, increases the number of packets collisions. Prioritizing the rebroadcast operation at each node with respect to different network parameters such as a number of duplicated packets, network local and global density also are tackled in this paper. 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 presents a detailed description of our algorithm and its component. Section 4 provides the performance evaluation of our algorithm. Finally, Section 5 concludes this study and outlines our future work.

II. RELATED WORK AND MOTIVATION

In this section, we review various solutions that were proposed to mitigate the BSP. In fact, broadcast storm problem in MANETs have been investigated widely in the literature [9]

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[10] [13], however, due to space limitation it is impossible to accommodate all the related studies here; thus we restrict our discussion to a number of well known recently proposed solutions. In [5], a fixed probabilistic scheme is suggested that allows every node that receives a RREO packet for the first time to rebroadcast it to all nodes in the network with a certain value of probability *P*, (i.e. 0.7), irrespective of the network density. The fixed probabilistic is improved in [11] by using, particularly, Smart Probabilistic Scheme (SPS), which considers the level of nodes density. This scheme divides the MANET into four logical groups of density spectrum; namely, sparse, medium sparse, dense and high dense levels. Then, it assigns a deferent forward value of *P* for each level. The density information is collected by broadcasting HELLO packets every second for 1-hop to construct a neighbourhood list at each node. After that, the node can decide in which four levels it belongs to by comparing its neighbourhood list with the average network neighbours. In general, the probabilistic scheme can be improved if it is used with other schemes.

A dynamic probabilistic neighbour coverage route discovery is proposed in [12], to mitigate the broadcast storm problem which is associated with the route discovery phase. The proposed scheme allows each node to determine its forwarding probability according to the network density and set of neighbours which are covered by the previous transmission. A node adds the list of its neighbours with RREQ packet and forwards it to all nodes within its transmission range. When the receiver receives the RREQ packet, it calculates the difference between its neighbour and the list of neighbours that have been already covered by the broadcast operation. The forwarding probability is set low if a large percentage of its 1-hop neighbours are covered by the broadcast, and vice versa.

In counter-based scheme [5] each node retransmits the received packet after a random waiting time period, if its counter exceeds a pre-determined counter threshold. The performance of counter-based scheme is improved with the fixed probabilistic scheme and achieves high reachability with minimum retransmission [6]. The same approach is enhanced in [13], namely Hybrid Probabilistic Counter scheme (HPC), to enable each node to rebroadcast the packet with probability that is calculated by using an exponential counter function *f(C)*. This function uses a number of duplicated packets as an input to adjust the retransmission probability. However, a random delay timer is used in those schemes [6] [13], which leads to retransmission simultaneous broadcast problem, and thus increases the collisions rate between nodes.

Another probabilistic-counter based scheme is proposed in [7] to mitigate the BSP during the route discovery phase. This scheme adjusts the retransmission probability based on the number of duplicated RREQ packets counter, which is calculated during a fixed random timer. The main shortcoming of this is that the decision to rebroadcast is made after a fixed timer which is set and adjusted regardless of network density. In addition, the retransmission probability is adjusted according to a small constant *d* which is not explicitly specified.

Motivated by the above discussion and observations, we propose in this study a new Distributed Route Discovery (DRD) to handle the route discovery and broadcast communication efficiently MANETs. For more clarity, we can summarize our contribution in this paper by presenting a DRD which is characterised by the following abilities and features: (i) it suppresses the broadcast storm in dense network and overcomes the disconnected network problem; (ii) DRD considers the network density (i.e. number of neighbours and redundant packets) while calculating the rebroadcast probability and the timer and (iii) DRD adjusts the timer and recalculate rebroadcast probability according to the network density.

III. The Proposed distributed route discovery

In conventional ad hoc on demand distance vector routing protocol AODV [3], when a node starts to send a data packet to a specific destination, it first checks whether it has a valid route or not. The valid route is then used immediately by the source if it is already established. Otherwise, the source initiates a route request session and broadcast RREQ packet to its neighbours. All neighbours that receive the RREQ packet, blindly rebroadcasts it, which causes broadcast storm problem. In this section we describe our proposed DRD, which is proposed to overcome various problems associated with broadcast communication in MANETs. The following sections discuss DRD which is described in steps in Fig.1.

A. Timer and probabilistic function

If the sources' neighbour receives the RREQ for the first time, the neighbour initialises a random waiting time which is adjusted according to the network density. In dense network, a waiting time should be set longer as many relay nodes receive the same message and try to rebroadcast it. Using density as a factor in calculating the waiting time for each node can reduce the possibility for having more than one node to rebroadcast at the same time. As a result, the simultaneous broadcast problem between nodes and packet collision can be reduced. The following formula is used to set the timer in the proposed scheme.

$$DT_i = (0{,}1 - e^{-(\frac{N_{local}}{N_{global}})}) \times t \tag{1}$$

Where DT_i refers to the node initial Density Timer, N_{local} is the local number of one hop neighbours for the node, N_{global} is the maximum global possible network density, and t is a random delay number between $[0, 10^{-3}]$. This interval value is a simulation based and adopted to reduce both a number of rebroadcasted nodes and collision rates packets. The same value is also used in [14][15]. We have conducted extensive simulation scenarios to find the approximate value for N_{local} and N_{global} as in table 1. Similarly, a rebroadcast probability for nodes that relay the RREQ packet should consider the nodes density during the rebroadcast calculation. When the network density is high, where the number of possible relay nodes is increased, the value rebroadcast probability should be set low. Otherwise, the large number of relay nodes with high probability cause to the broadcast storm. Upon receiving the

RREQ, each relay node calculates its initial Density rebroadcast Probability DP_i by using the following formula:

$$DP_i = RAND\ (0, e^{-(\frac{N_{local}}{N_{global}})}) \qquad (2)$$

SCHEME: DISTRIBUTED ROUTE DISCOVERY (DRD)

```
1:NLOCAL ←GETNUMBER OF ONE HOPE NEIGHBOUR ()
2:NGLOBAL← GET MAXIMUM NETWORK DENSITY ()
3:IF RREQ PACKET RECEIVED FOR THE FIRST TIME() = TRUE {
4:    INITIALIZE DENSITY TIMER: DTi=(0,1- e-NLOCAL/NGLOBAL * t)
5:    INITIALIZE DENSITY PROBABILITY:  DPi = RAND (0,e-  NLOCAL/NGLOBAL)
6:END_IF
7:WHILE (TC <WTH) {
8:WHILE (DTi IS NOT EXPEIRED) {
9:GET_NUMBER _COPY () {NC=NC+1}
10: IF THE SAME RREQ PACKET RECEIVED() = TRUE{
11:  TIMER_EXTISION (){DTi+1 = DTi (NC-1)}}
12:  PROBABILITY_READJUSTING(){DPi+1= DPi/NC-1}
13:  INCREASE WAITING TIMER COUNTER : TC =  TC+1}
14:  END_IF
15 :    END_WHILE
16:  END_WHILE
17:   WHILE(COUNTER < 3) {
18:   IF (NC-1 ==0 | | NLOCAL == 0) {
19:    WAIT_ADDITIOAL _TIME()
20:          COUNTER++}
21:     END_IF
22: END_WHILE
23: RN←RANDOMNUMBER(0,1)
24: IF RN<DP = TRUE
25: REBROADCAST_RREQ()
26:  ELSE
27:  DROP_RREQ()
28: END_IF
```

Figure1: Description of DRD.

B. Timer extension and recalculating probability

For each time the timer is expired, the relay node checks weather it receives duplicated RREQ messages during the waiting time DT_i. If it is the case, this indicates that more than one neighbour have already performed the rebroadcast operation. In such a case, DRD extends the timer to maximise the probability for each node to receive more duplicated RREQ packets, thus decreases its probability to participate in the rebroadcasting process. The following formula is used to extend the timer:

$$DT_i+1 = DT_i\ (N_C-1) \qquad (3)$$

Where N_C is the number of received RREQ packets copy within DT_i interval, and DT_{i+1} is the next waiting time interval. The next value of the density rebroadcast probability DP_{i+1} is calculated using the following formula:

$$DP_{i+1}= DPi/(N_C-1) \qquad (4)$$

We refer to the equation 11 and 12 in lines 4 and 5 in figure 1. To avoid facing the infinity problem while extending the timing process, we set two control parameters. The first is a waiting Timer Counter TC to count for the number of times each node extends its timer. The second is a waiting threshold W_{th}, which represents the maximum number of times that each node has to wait for. Note that, W_{th} is a designed network parameter that should be set according to the network density.

TABLE1: SAMPLE OF THE VALUES OF THAT USED IN THE EQUATIONS.

No.of Nodes	Network Size	N_{local}	N_{global}	DT_i	DP_i
50	500m x 500m	6	8	52 x10^{-5}	0.47
100	750m x 70m	57	64	58 x10^{-5}	0.41
200	1000m x 1000m	46	60	23 x10^{-5}	0.64
300	1000m x 1000m	70	95	51x10^{-5}	0.48

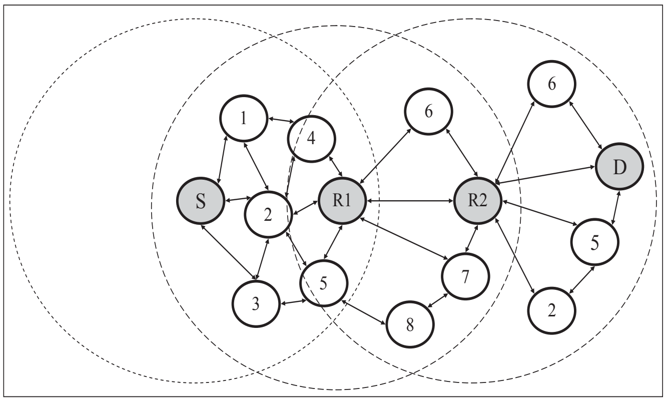

Figure 2: Example of DRD algorithm.

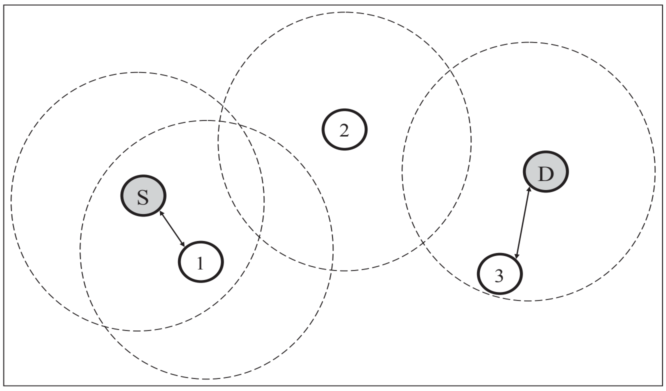

Figure 3: Example of disconnected network scenario.

In other words, in a dense network, W_{th} should be set high and low in a sparse network. The extension of the timer process is terminated if the number of TC reaches the above W_{th} threshold. Step 11 and step 12 in Fig.1 are used to extend and readjust the timer and the rebroadcast probability.

C. The connection gap and disconnected network

A connection gap between nodes is highly possible in sparse MANET, when no duplicated RREQ is received during the timer lifetime, and the relay node has no neighbours. To overcome this problem the relay node buffers the RREQ for an additional waiting time (the same value of previous timer DT_{i+1}) in order to prevent RREQ to die out. Once the relay node deducts at least one neighbour within its transmission range, it should rebroadcast with probability 1.

A. Illustrative example

An illustrative example for DRD is provided in Fig.2 and Fig.3. For instance, in Fig.2, if Source S needs to open a connection to the Destination D, it will initiate sending RREQ packet to all its neighbours within its transmission range. Nodes 1, 2, 3, 4 and 5 will receive this transmission. All these nodes, i.e., 1, 2, 3, 4 and 5, after receiving RREQ packet for the first time, execute DRD algorithm to optimise rebroadcast process during the route discovery operation. First, nodes 1, 2, 3, 4, 5 and R1 upon receiving RREQ packet from the source node S, they will wait the whole period of DT_i before they decide to rebroadcast again or discard the RREQ packet, if it obtained it from other nodes. Suppose that nodes' R1 timer is expired first compared to other nodes, due to for example, located at sparse area. Nodes 1, 2, 3, 4 and 5 receive duplicated RREQ packet form node R1, while nodes 6, 7, 8 and R2 receive RREQ for the first time from R1. Therefore, those nodes execute DRP algorithm again, and nodes 1, 2, 3, 4 and 5 extend their timer DT_{i+1} and decrease retransmission probability DP_{i+1}, as the RREQ message has been already received by those nodes. The timer extension process and re-adjusting value of DP_{i+1} will stop if the number of timer extension (i.e. TC) exceeds the maximum number of waiting time (i.e. W_{th}) that is allowed at each node. Similarly, assume that the timer of node 8 expires first; all of its neighbours run the DRD scheme again to suppress any unnecessary retransmission. Finally, the optimal route that DRD creates is S->R1->R2->D. Fig.3 illustrates the worst experienced scenario where there is no relay node can receive RREQ packet and forward it to other nodes. For example, suppose that source node S sends RREQ packet and there is only one relay node (i.e. node 1) can receive this packet. In this case, node 1 will hold the packet until its timer is expired. Rebroadcast from node 1 is considered useless and the RREQ packet is likely to die out, as there is no relay node to receive it. DRP overcomes this problem by allowing each node to maintain the set of 1-hop neighbours list. If node A does not have neighbours or does not hear a duplicated RREQ packet during its timer lifetime, it will hold the RREQ packet for extra time until, for example, it approaches node 2 or 3, or vice versa.

IV. PERFORMANCE ANALYSIS

A. Simulation setup

To evaluate and compare the performance of the broadcast schemes discussed above, we used NS-2.34 as the simulation platform designed by researchers at Berkeley University [16]. For each data points in all the figures, at least 30 experiments are used, each one represents different network topology with 95% confidence intervals. The random waypoint model [17] is used as the mobility model. In this model, mobile nodes move free and randomly without boundary restrictions. Application layer at each node generates CBR traffic. The rest of parameters exist in table 2. It is worth stating that we have almost used the same parameters used in [12]. Due to its high capability in MANETs, AODV routing has been adopted in our experiments. DRD, SF, and HPC have been examined within the context of AODV routing protocol. In our experiments, we refer to our proposed scheme as AODV-DRD and we investigate its performance, in comparison with both AODV-SF [3] and AODV-HPC [12] that we discussed in sections 1 and 2 respectively.

B. Performance Metrics

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

- ***RREQ Collision Number*:** represents the average number of RREQ packets dropped and failed to reach the nodes in the network.
- ***RREQ Rebroadcast Number:*** Represents the total number of RREQ packets that each node generates and rebroadcasts during the period of simulation time.

C. SCENARIO 1: *Impact of Network Density*

In this scenario the network density varies from low (25 nodes) to high (200 nodes) placed in a network area of size 1000m x 1000m. Each node has a random maximum speed of 2m/s. Traffic load is set to 20 flows for each scenario with 8 data packets/second.

- *RREQ Collision Number*

To measure the impact of using AODV-DRD and other broadcast schemes on minimizing the channel contention, we calculated the RREQ collision rate that is generated by each scheme. Fig.4 shows that the collisions rate is increased by all the schemes as the number of nodes increases. Notice that when the density increases the number of candidates for rebroadcasting RREQ increases. As a result, the RREQ packets collision increases. AODV-DRD reduces the possibility of having more than two nodes to rebroadcast at the same slot time. As a result, the broadcast collision problem is suppressed. Fig.4 also depicts that the collision rate of AODV-DRD is reduced by approximately 45% compared to AODV-SF and 25% compared to AODV-HPC.

- *RREQ Rebroadcast Number*

The RREQ rebroadcast number represents the number of nodes that receive RREQ packet and rebroadcast it successfully. To study the effect of varying network density on the number of generated RREQ packets that incurred by AODV-DRD and AODV-SF, we calculated the number of disseminated RREQ packets for each scheme. The figure shows that as the number of nodes increase the number of RREQ packet increase, as many nodes receive and rebroadcast the same RREQ packet. In contrast, AODV-DRD generates a minimum number of RREQ packets. Fig.5 depicts that the collision rate of AODV-DRD is reduced by approximately 65% and 35% compared to AODV-SF and AODV-HPC respectively.

D. SCENARIO 2: *Impact of number of connections*

In this scenario, each broadcast scheme is evaluated under different offered traffic load, varies from 1-40.

- *RREQ Collision Rate*

The connections between sources and destinations are selected randomly. The network topology is 1000m x1000m with 150 nodes are deployed. Fig.6 illustrates the number of RREQ packet collisions that occurred during the simulation time for the three broadcast schemes. Clearly, AODV-DRD has the best performance compared to its two counterparts. This is due to using extension timer technique and readjusting rebroadcast probability upon receiving a duplicated RREQ packet at each node. Fig.6 also reveals that for a given connection point, AODV-DRD outperforms AODV-SF and AODV-HPC. In particular, the collision rate of DRD-AODV is about 19% lower than that of AODV-HPC.

- *REQ Rebroadcast Number*

Fig.7 depicts that the RREQ rebroadcast number that generated by the routing schemes increases with while growing the offered load. This is because; as the number of flow increases, the number of connection between sources and destinations increase proportionally. In fact, to open any connection between the source and destinations, the RREQ packet should be initiated and rebroadcasted. For instance, when the number of connections increases from 5 to 40, the routing overhead generated by AODV-DRD is reduced by approximately 20% compared to AODV-HPC.

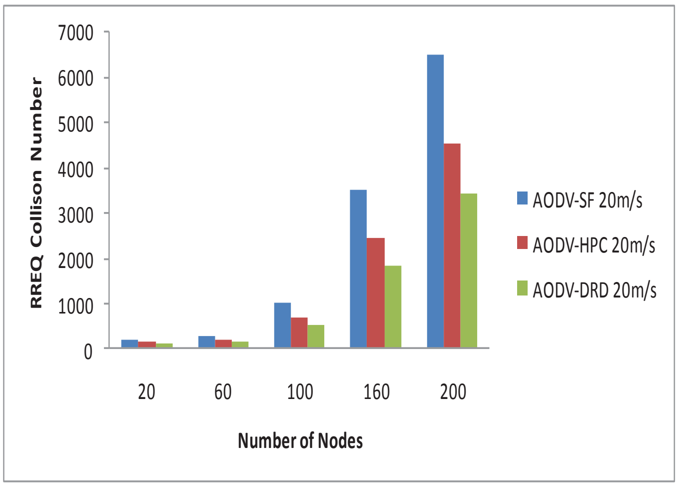

Figure 4: RREQ collision No vs. No of connections.

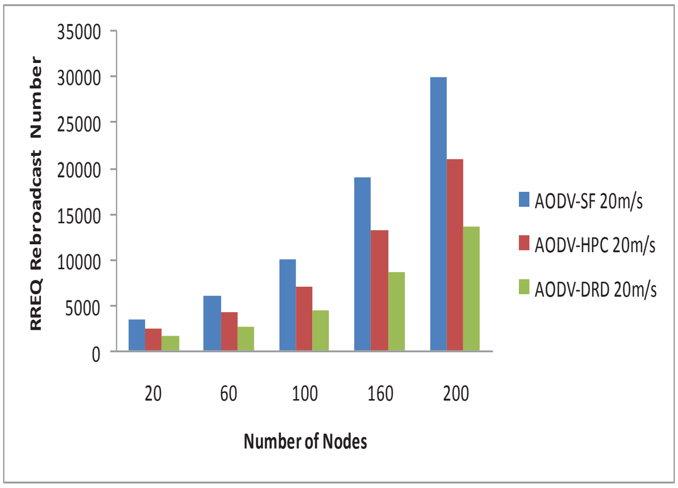

Figure 5: RREQ Rebroadcast No vs. No of connections.

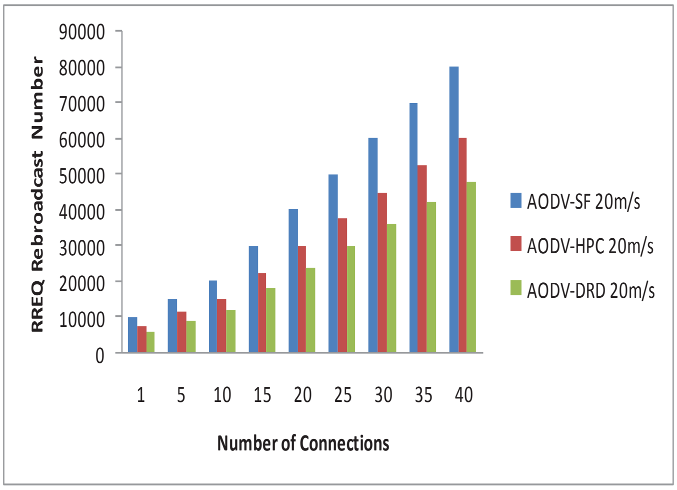

Figure6**:** RREQ Rebroadcast No vs. No of nodes.

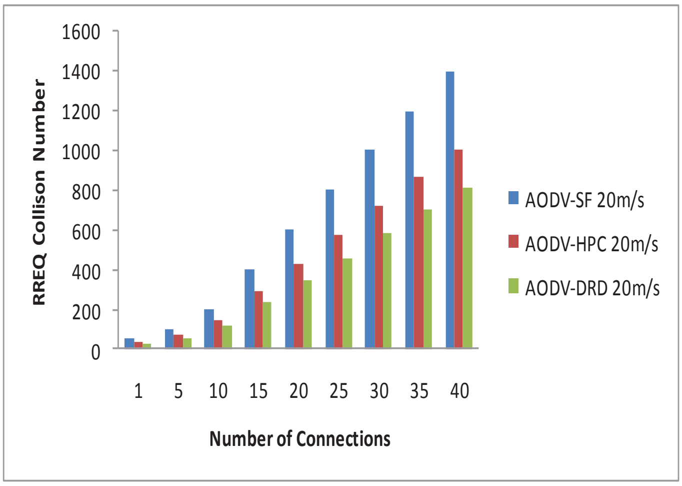

Figure 7: RREQ collision No vs. No of connections.

TABLE2: SUMMERY OF THE PARAMETERS USED IN THE SIMULATIONS.

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	$1000 \times 1000\ m^2$
Nodes speed	20 m/sec
Number of node	20-200 nodes
Number of connection	1-40
Data traffic	CBR
Mobility model	Random Way-Point
Number of trials	30 trials

V. CONCLUSION AND FUTURE WORK

In this paper, we investigate the broadcast and route discovery problem in MANETs. We have proposed a new AODV-DRD broadcast scheme, to mitigate different broadcast storm problems that are usually associated with the route discovery phase. We adopted the random waypoint to evaluate the performance of AODV-DRD, considering different parameters such as node density and connections. We have conducted simulation experiments and our results confirm the superiority of the proposed AODV-DRD compared to the AODV based broadcast schemes including the well known AODV-SF and AODV HCP. We believe that our results have distinct significance for MANETs designers to develop broadcast based applications with prescribed degrees of coverage and connectivity. Our future work includes extending the AODV-DRD approach to other communication models and different mobility levels within more scenarios and different communication protocols.

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