EFFICIENT BROADCASTING IN MANETS USING DIRECTIONAL ANTENNAS

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ABSTRACT
Broadcast has been widely used in mobile ad hoc networks (MANETs) as a communication means to disseminate information to all reachable nodes. However, the conventional broadcast scheme that broadcast packets omni directionally suffers from several drawbacks: excessive amount of redundant traffic, exaggerated interference/contention among neighboring nodes, and limited coverage (as a result of contention/collision). This is termed as the broadcast storm problem. In this paper, we address this problem in MANETs with the use of directional antennas. We propose a broadcast protocol called directional broadcast protocol (DBP) to alleviate broadcast storm problem in ad hoc networks using directional antennas. Compared with omni directional scheme DBP uses minimum number of forward nodes to relay the broadcast packet, while the number of forward directions that each forward node uses in transmission is significantly reduced. With lower broadcast redundancy, DBP is more bandwidth and energy efficient. DBP is based on neighbor discovery information and does not rely on location or angle-of –arrival information. Two special cases of DBP are discussed: the first one preserves shortest path in reactive routing discoveries; the second one uses both directional transmission and reception mode to minimize broadcast redundancy. An extensive simulation study using ns- 2.30 shows that DBP significantly outperforms the omni directional broadcast protocols.

Keywords: Mobile ad hoc networks, Broadcast Storm problem, Directional antenna.

1 INTRODUCTION

Ad hoc networks consist of mobile nodes that autonomously establish connectivity via multihop wireless communications . Without relying on any existing preconfigured network infrastructure or centralized control, ad hoc networks are useful in many situations where impromptu communication facilities are required , such as battlefield communication facilities and disaster relief missions.Other applications of ad hoc networks include data acquisition in hostile territories, virtual classrooms and temporary local area networks.

Broadcast has been widely used in mobile ad hoc networks (MANETs) as a communication means to disseminate information to all reachable nodes. It has been used in, for example, routing protocols such as DSR [17], AODV [18], ZRP [19] and LAR [20], to discover routes. The simplest way of realizing broadcasts is via flooding – upon receipt of a broadcast packet, a node simply sends it out in all directions. In particular, packets are conventionally transmitted with the use of omnidirectional antennas, and neighboring nodes receive and forward these packets omnidirectionally. This, however, generates an excessive amount of redundant traffic and exaggerates interference in the shared medium among neighboring nodes. Moreover, because of the frequent contention and transmission collision among neighboring nodes, some nodes may not receive the broadcast packet. This is termed as the broadcast storm problem.Recently, use of directional antennas for data transmission has received much attention as it demonstrates the capability of increasing the network capacity with spatial reuse, and mitigating the interference and contention among neighboring nodes. Succinctly, directional antennas [23,24] concentrate more energy in a certain direction, and hence can achieve higher signal-interference-ratio and narrower beam width and mitigate inter-symbol interference (ISI) due to multipath fading. These features have been judiciously used to maximize the number of on-going connections and to reduce the interference and contention [21,22, 24, 25]. Motivated by the above research work, we consider in this paper use of directional antennas to mitigate the broadcast storm problem. The objective is to ensure broadcast packets reach most, if not all, nodes, and yet reduce the amount of redundant traffic.

In this paper we propose a frame work to design a broadcast protocol called directional broadcast protocol (DBP) to alleviate broadcast storm problem in ad hoc networks using directional antennas. Compared with omnidirectional scheme DBP uses minimum number of forward nodes to relay the broadcast packet, while the number of forward directions that each forward node uses in transmission is significantly reduced. With lower broadcast redundancy, DBP is more bandwidth and energy efficient. DBP is based on neighbor discovery information and does not rely on location or angle-of –arrival information. Two special cases of DBP are discussed : the first one preserves shortest path in reactive routing discoveries ; the second one uses both directional transmission and reception mode to minimize broadcast redundancy. DBP is a localized protocol.

2 RELATED WORKS

Williams and Camp [2] conducted a comparative study on existing broadcast schemes for mobile ad hoc networks.We review the basic ideas of these schemes with a special focus on that are closely related to our work.

1. Flooding is the simplest, while the most reliable, way of broadcast, where each node retransmits (forwards) the (broadcast) packet exactly once upon receiving it for the first time. The major draw back of flooding is its high cost and excessive redundancy, which causes the broadcast storm problem[1].Ho et al. [3] proposed to achieve reliable broadcast and multicast in highly dynamic networks. Jetcheva et al. [4] aim to support broadcast and multicast in ad hoc networks characterized by low density and /or high mobility.
2. Probability based schemes allow a node to forward a packet with certain probability p when it receives the packet for the first time. Ni et al. [1] introduce the broadcast storm problem and propose various probability-based and area-based solutions. The studies of [1,5] have shown that probabilistic broadcasts incur significantly lower overhead compared to blind flooding while maintaining a high degree of propagation for the broadcast messages.
3. Counter-based , distance-based , and position-based schemes, is also proposed by Ni et al. [1]. The basic idea is to collect duplicate packets received from neighbors for a random period of time after the first packet is received, and distill knowledge from these packets to make a forwarding decision. For the counter-based scheme, the knowledge is the total number of received duplicates, and the packet is forwarded if it is below a counter threshold. For the distance-based scheme, the knowledge is the minimum distance from the node to the sender of these packets, which is an estimation of the node's additional (broadcast) coverage area, and the packet is forwarded if it is over a distance threshold. The location-based scheme leverages the precise location information to provide a more accurate estimation of the additional coverage area. Neighbor-based schemes avoid broadcast storm by forwarding the packet to a smaller subset of nodes while maintaining comparable coverage. The selection of nodes is mostly based on the knowledge about a node's two-hop and, possibly, one- hop neighbors. Based on whether the forwarding decision is made by the sender or the receiver, the schemes can be further classified [6] into neighbor designed [7,8,9,10] and self-pruning [6,11,12,13]. Lim and Kim [8] propose a simple neighbor-based scheme in which a node includes its one-hop neighbor list,available via neighbor discovery, inside its broadcast packet. A node receiving a packet compares its neighbor list to the sender's neighbor list. If the receiving node could not reach any additional node, it would not forward the packet; or forward it, otherwise.

The work of [14,15] applies directional antennas to reducing routing overhead in ad hoc networks. Nasipuri et al. [14] present two protocols that apply directional antenna to minimizing the query flood by forwarding the (query) packet in the sectors along the direction of the destination.

Choudhury and Vaidya [15] present a sweeping mechanism that avoids forwarding request in the direction where the channel is busy. Hu et al.'s work [16] applies directional antennas to mitigating the broadcast storm problem. The work presents three schemes: on/off directional broadcast, relay-node-based directional broadcast, and location-based directional broadcast. The on/off directional broadcast is a special case of our counter-based directional broadcast scheme. The relay-node-based directional broadcast applies directional antennas to neighbor-designed, one-hop neighbor based broadcast; while our neighbor-based scheme applies directional antennas to self-pruning, one-hop neighbor based broadcast. The location-based directional broadcast attempts to approximate the (directional) additional coverage area; while our location-based scheme provides a linear estimate of the additional coverage area.

3 PROPOSED FRAMEWORK

With omni directional antennas, the distribution of energy in all directions other than just the intended direction generates unnecessary interference to other nodes and considerably reduces network capacity. On the other hand, with directional transmission both transmission range and spatial reuse can be substantially enhanced by having nodes concentrate transmitted energy only towards their destination's direction, thereby achieving higher signal to noise ratio.

When there is a need to utilize only the directional characteristics, the demands are more since this is possible only when the node which wants to transmit and the node which wants to receive are synchronized with their respective related modes (i.e.). One node is in the transmit mode and other is in the receive mode and are pointing towards each other as shown in Figure 1.

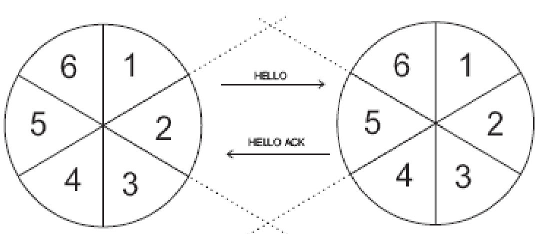

Figure 1 Basic mechanism with six sectors, M=6

In DBP each node is required to record the received power of the hello packet from the farthest node (weakest signal) in each beam[12]. Let us denote this power as P_f .Upon receiving a broadcast packet and after the expiration of RDT (random delay timer), the node forwards the packet on all the beams except the ones on which it received the packet. For each beam, it includes P_f of the corresponding beam in the packet header. Whenever a node receives this packet, it retrieves its received power, say P_r and calculates the ratio of P_f / P_r. This is the probability with which it will re-broadcast. In addition, the order of rebroadcast will be vertically opposite beams followed by their adjacent beams. Similarly neighbor-less and busy sectors will he ignored. Therefore, in the nodes which are very close to the broadcast originator have very little probability to rebroadcast. There is still the option of eliminating the idea of very close nodes forwarding at all. With this option, in each sector only nodes which receive the packet at a power less than or equal to $2*P_f$ will retransmit with probability P_f / P_r . Note that the farthest node in each sector has probability 1 to rebroadcast. Figure 2 illustrates this idea, where nodes (b) and (c) do not forward at all while nodes (d) and (e) forward with probability P_f / P_r . Node (f) will definitely forward as its farthest node in that direction.

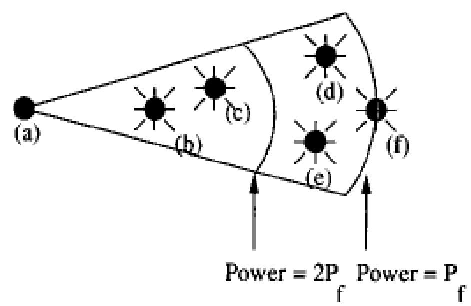

Fig 2 Directional transmission based on received signal strength

As the network grows, the number of control packets increases in Omni directional case exponentially resulting in Broadcast storm problem [1] as shown in Figures 3(a) and 3(b). Three cases to calculate the number of broadcast packets generated for a square lattice size of N nodes are considered

1.Omni Directional Transmission: Transmits in all possible directions 2.Blind Directional Transmission: Transmits in all directions other than the direction it received 3.Smart Directional Transmission: Transmits packets in controlled manner with the help of Routing Protocol in the network layer.

Let N be the number of nodes and T be the transfer time, then for Omni directional antenna transmission, the transfer time is calculated as,

$$T = (N - 1) * 10 + 8 * (N - 1)^2 + 3 \qquad (1)$$

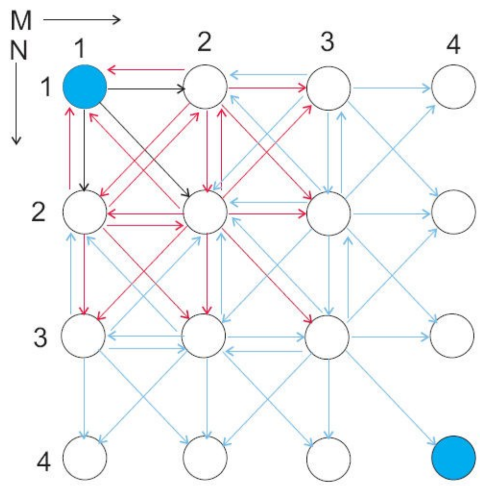

Figure 3(a) The broadcast storm problem in grid topology

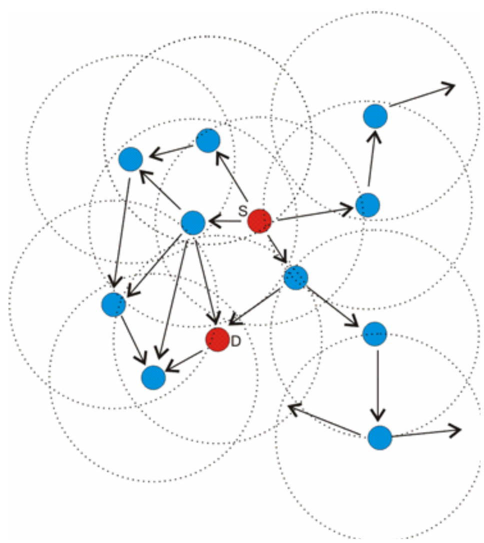

Figure 3(b) Representation of broadcast storm scenario in random topology

For Blind Directional Antenna transmission,

$$T = (N -1) * 8+7 * (N -1)^2 + 3 \qquad (2)$$

For Smart Directional antenna transmission,

$$T = (N – 1) \qquad (3)$$

Figure 4 shows the number of control packets generated for a variety of lattice sizes. The number of chains is same as the number of nodes in each chain resulting in square lattices. The total number of nodes is shown in X axis. There is reduction in control packets for Blind directional antenna and a drastic decrease for Smart directional case.

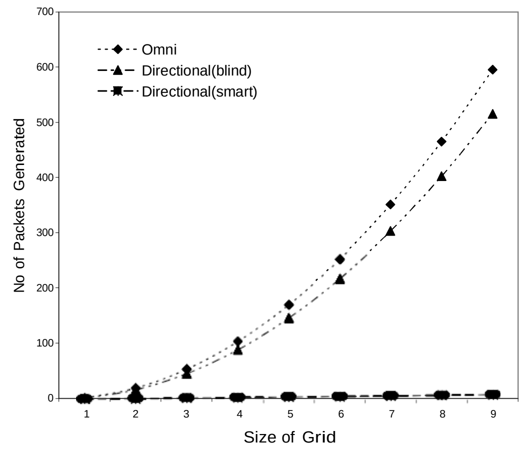

Figure 4. Number of control packets generated in a lattice network

4 PERFORMANCE EVALUATION

The Simulations are performed in Ns-2.30 whose parameters are tuned to model the Lucent WaveLan card at a 2 Mbps data rate. The simulator was modified to incorporate the Directional antenna. In the Simulator, the effective transmission range is set to be 250 meters, and the interfering rang is 550 meters for omni directional antenna. The throughput plots and number of broadcast packets generated for the omni-directional case using 802.11 MAC protocol are shown.

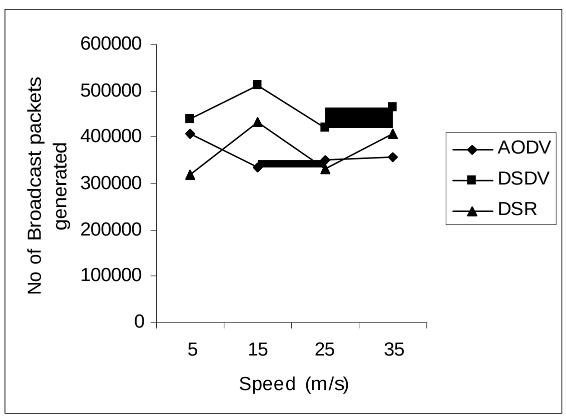

Figure 5 Number of broadcast packets generated for 100 nodes with 10 connections

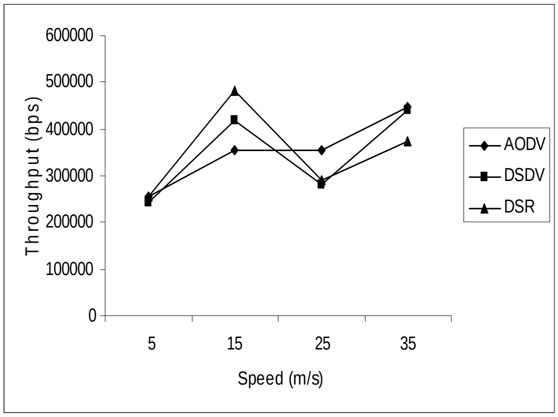

Figure 6 Throughput generated for 100 nodes with 10 connections

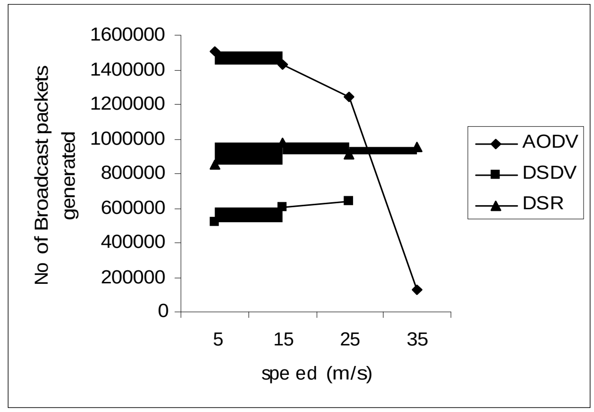

Figure 9 Number of broadcast packets generated for 100 nodes with 30 connections

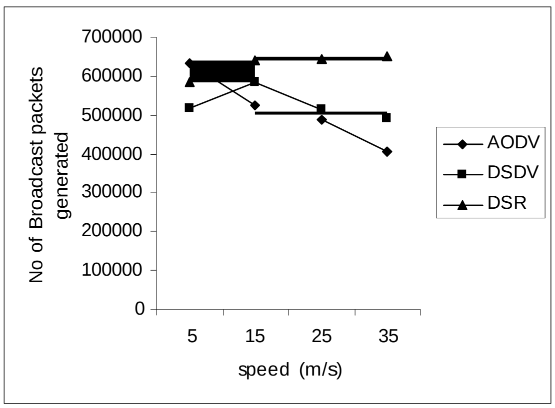

Figure 7 Number of broadcast packets generated for 100 nodes with 20 connections

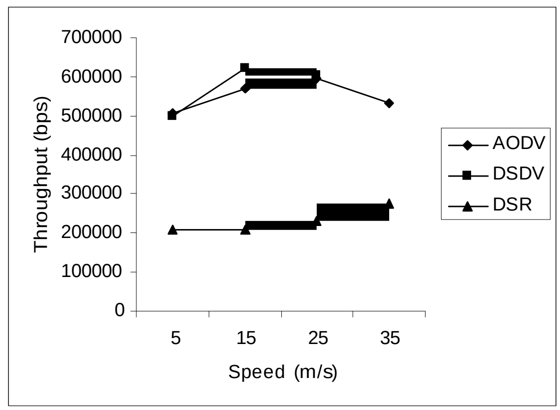

Figure 10 Throughput generated for 100 nodes with 30 connections

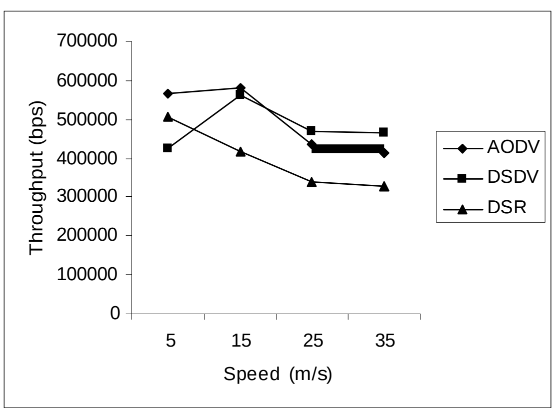

Figure 8 Throughput generated for 100 nodes with 20 connections

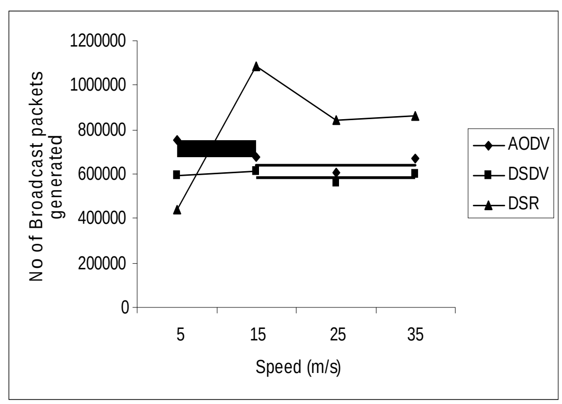

Figure 11 Number of broadcast packets generated for 100 nodes with 40 connections

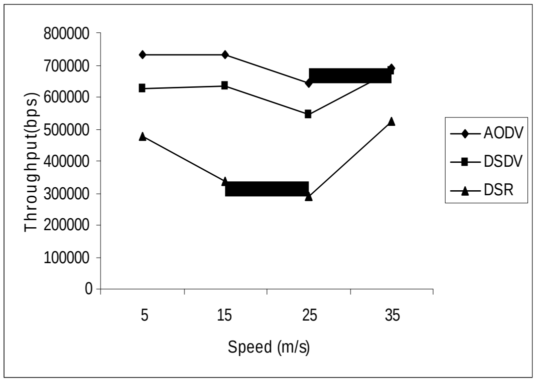

Figure 12 Throughput generated for 100 nodes with 40 connections

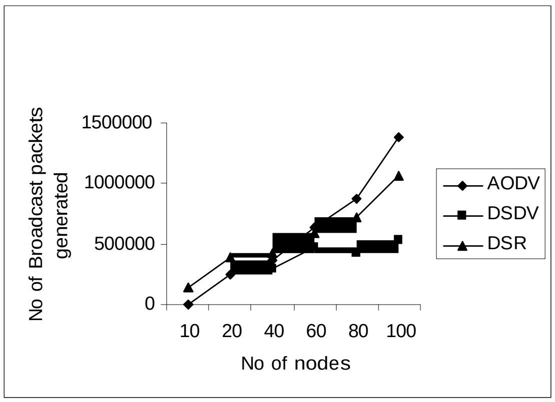

Figure 13 Number of broadcast packets generated with increasing number of nodes

From the simulated results the overhead is high in terms of broadcast packets since DSDV broadcasts periodic HELLO messages to its neighbors, and needs to send control messages more frequently than DSR and AODV to find and repair routes. The simulations in this work show that DSR performs better than AODV for low traffic loads, since it discovers routes more efficiently. At higher traffic loads, however, AODV performs better than DSR due to less additional load being imposed by source routes in data packets. The realistic scenarios were examined to get an understanding on how the protocols would behave in an environment more realistic than the random scenarios. DSR and AODV managed to deliver higher throughput when compared to DSDV.

5 CONCLUSION

The simulations presented here clearly show that there is a need for efficient broadcast protocol specifically tuned to the characteristics of ad-hoc networks. The mobility metric used throughout the study explicitly shows how the examined protocols behave for various degrees of relative node motion. The mobility metric is explicitly designed to capture the kind of motion important for an ad-hoc network – the relative motion of nodes. It can be used for any continuous node motion. In networks with a dynamic topology, proactive protocols such as DSDV have considerable difficulties in maintaining valid routes, and lose many packets because of that. With increasing mobility, its strive to continuously maintain routes to every node increases network load as updates become larger.

The results confirm most of the properties found in the random scenarios. DSDV had considerable difficulties in handling most scenarios even though the mobility was kept rather low. Both DSR and AODV performed quite well for almost all examined scenarios, while DSDV had serious performance problems.

Through simulations and analytical models it is proved that, the overall performance of the network is increased by reducing the broadcast packets to a larger extent using directional antenna. The throughput is increased to a large extent from source node to destination node.

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