Hybrid Position-Based $3D$ Routing Algorithms with Partial Flooding

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Abstract

Position-based routing algorithms use the location information to reduce routing overhead in mobile ad-hoc networks. In this paper we propose two position-based routing algorithms which combine progress-based routing with restricted directional flooding-based routing algorithms for routing in 3 dimensional environments ($3D$). The first algorithm $3D\_ABLAR(m)$ chooses m neighbors according to a space-partition heuristic and forwards the message to all these nodes. The second algorithm (C,G)-$3D\_ABLAR(m)$-(C,G) uses progress-based routing until a local minimum is reached. The algorithm then switches to the first algorithm for one step and then progress-based routing is resumed. We evaluate our algorithm and compare it with current routing algorithms. The simulation results show a significant improvement in delivery rate (99% compared to 63%) and reduction in traffic (up to 50%).

Keywords — *Position-based routing; directional flooding; ad-hoc networks.*

1 Introduction

Mobile ad-hoc networks (MANETs) consist of wireless mobile hosts that communicate with each other, in the absence of a fixed infrastructure. Since mobile ad-hoc networks change their topology frequently and without notice, routing in such networks is a challenging problem. The authors in [2] classified the routing algorithms in MANETs as begin of two basic types: *topology-based routing* [1], [11] and *position-based routing* [2], [5]. Topology-based routing algorithms use flooding to perform the packet forwarding. They can be further divided into *proactive* and *reactive* approaches. Topology-based routing can usually find the shortest path, in number of hops, between each pair of nodes. However, it can be difficult for these routing methods to handle large ad hoc networks with many nodes or with frequently changing connectivity among nodes. Position-based routing algorithms use position information such that the packet is forwarded in the geographical direction of the destination. In this type of routing, the node forwards the message based on the position of the node itself, the position of the destination and the position of the nodes to which it can communicate directly. Position-based routing is scalable to a large number of network nodes and is efficient when nodes move frequently.

There are two main types of packet-forwarding strategies for position-based routing [2]: 1) One neighbor forwarding: where the node containing the packet forwards it to exactly one of its neighbors, Greedy [8], Compass [7], Most forwarding [4] and AB algorithms [9] are some examples of this strategy. 2) Restricted directional flooding: where the node forwards the packet to more than one hop neighbors that are located closer to the destination than the forwarding node itself. Distance Routing Effect Algorithm for Mobility (DREAM) [6] and the geocasting based Location-Aided Routing (LAR) [3] are some examples for this strategy. These algorithms are widely used in 2 dimensional ($2D$) MANETs, but their performance on MANETs embedded in three dimensional space is not well studied. In this paper we propose two routing algorithms which combine progress-based routing with restricted directional flooding-based routing algorithms for routing in $3D$ environments. The first algorithm, $3D\_ABLAR(m)$, chooses m neighbors according to a space partition heuristics and forwards the message to all these nodes. The second algorithm, (C,G)-$3D\_ABLAR(m)$-(C,G), uses progress-based routing until a local minimum (when the node fails to find a neighbor that is geographically closer to the destination or fails to stay close to the direction of the destination) is reached. The algorithm then switches to $3D\_ABLAR(m)$ routing for one step and then progress-based routing is resumed.

Our simulation experiments on unit disk graphs show that the delivery rates of $3D\_ABLAR(m)$ and (C,G)-$3D\_ABLAR(m)$-(C,G) algorithms are significantly better than the studied progress-based routing algorithms (99% compared to 63%). The delivery rates are comparable to $3DLAR$ algorithms but with 50% less routing traffic.

The remainder of this paper is organized as follows. In next section we briefly review some related position-based routing algorithms. In Section 3 we introduce the proposed approaches. In Section 4 we present experimental results to demonstrate the much improved performance of the proposed method in comparison with existing techniques. We conclude in Section 5.

2 Preliminaries

2.1 The Network Model

We assume that the set of n wireless nodes is represented as a point set S in $3D$ space, each mobile host knows the coordinates (x,y,z) of its position. All network nodes have the same communication range of r such that two nodes are connected by an edge if the Euclidean distance between

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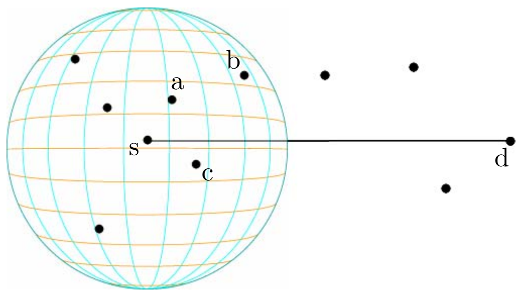

Figure 1. To route from s to d. GREEDY chooses b, COMPASS chooses c and AB-GREEDY chooses randomly between c and b as the next node.

them is at most r. The resulting graph is called a unit disk graph (UDG). For a node u, we denote the set of its neighbors by $N(u)$. Given a unit disk graph $UDG(S)$ corresponding to a set of points S, and a pair (s, d) where $s, d \in S$, the problem of position-based routing is to discover a path in $UDG(S)$ from s to d. At each point of the path, the decision of which node(s) to go to next is based on the positions of the current node c, the destination node d and $N(c)$. We are interested in the following performance measures for routing algorithms: the *delivery rate*, which is the percentage of times that the algorithm succeeds in delivering its packet, and the *network traffic*, the average ratio of the number of nodes the packet visits during the routing process to the number of nodes in the shortest path in the UDG.

2.2 Related Routing Algorithm

Greedy: the current node forwards the packet to the neighbor that minimizes the remaining distance to the destination. The same procedure is repeated until the destination node is reached.

Compass: the current node forwards the packet to the neighbor node that minimizes the angle between the current node, next node and the destination node locations. The same procedure is repeated until the destination node is reached.

AB algorithms: the algorithms pick one neighbor of the current node above the line passing through the current node and the destination node, and another neighbor below this line. Then the next node is chosen randomly or according some heuristic from these two neighbors. Figure 1 gives a small example of the choices made by the algorithms discussed above.

Compass, Greedy, AB and most of other progress based routing algorithms are known to fail to deliver the packet in a certain situations.

DREAM algorithm: the current node forwards the packet to all neighbors in the direction of the destination D. In order to determine if the neighbor node is in the direction of D or not, a node calculates the region that might

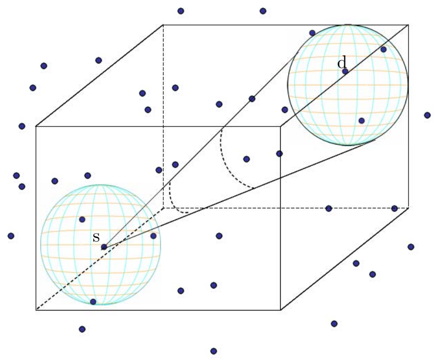

Figure 2. To route from s to d. DREAM will forward the packet to all the nodes inside the cone, 3DLAR will forward the packet to all nodes inside the cube.

contain D, called the expected region.

LAR algorithm: also uses the position information to restrict the flooding process during the route discovery phase of the flooding-based algorithms. With the available information of the destination node d, the source node s computes the *expected zone* for d as in DREAM and use this zone to define the flooding area, which is a cube. Figure 2 depicts how both algorithm works.

DREAM and LAR reduce the flooding traffic, but it still very high compared with progress-based routing.

3 Proposed Routing Algorithms

In the following we assume that the current node is c, the source node is s and the destination node is d. In the routing process the forwarding zone, defined as in [3], is a cube K with the two corners $s \pm \eta$ and $d \pm \eta$, η equal to r.

3.1 $3D\_ABLAR(m)$

This routing algorithm uses Compass or Greedy to choose a node from $N(c)$ called x_1. Define the plane $(P1)$ that passes through c, x_1, and the destination d. Define another plane $(P2)$ that passes through the vector (cd) and is perpendicular with $(P1)$. See Figure 3. We show two versions of this algorithm as follows:

3D_ABLAR(3): the current node c uses Compass algorithm to choose from $N(c)$ one node x_2 above the plane $P1$ and another node x_3 below $P1$ and then c forwards the packet to all x_1, x_2, x_3 if x_i is inside the cube K.

3D_ABLAR(5): c uses Compass algorithm to choose from $N(c)$ four neighbors x_2, x_3, x_4, x_5 each one in one side of the four regions that result for the intersection between $P1, P2$. And then c forwards the packet to all those selected neighbors x_i that are inside the cube K.

3.2 (G, C)-$3D\_ABLAR(m)$-(G, C)

G-3D_ABLAR(m)-G: uses Greedy routing until a local minimum (where progress to the destination is not possible) is reached. The algorithm then switches to

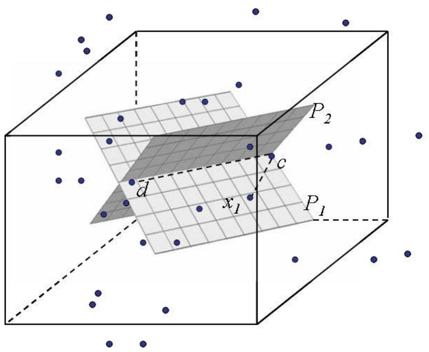

Figure 3. Plane $P1$ pass through c,d and x_1, plane $P2$ perpendicular to $P1$ and pass through the line sd. 3D_ABLAR(3) chooses 2 nodes one above $P1$ and one below $P1$, 3D_ABLAR(5) chooses 4 nodes one from each side that result from the 2 planes intersections.

$3D\_ABLAR(m)$ routing for one step and then Greedy routing is resumed.

C-3D_ABLAR(m)-C: uses Compass routing until a local minimum (fails to stay close to the direction of the destination) is reached. The algorithm then switches to $3D\_ABLAR(m)$ routing for one step and then Compass routing is resumed.

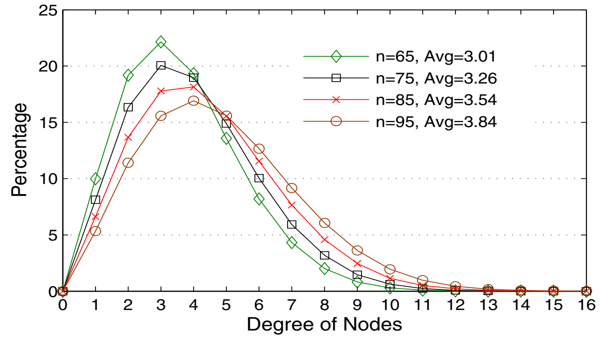

Figure 4. The histogram of average node degrees of the LCC in 10,000 generated UDG.

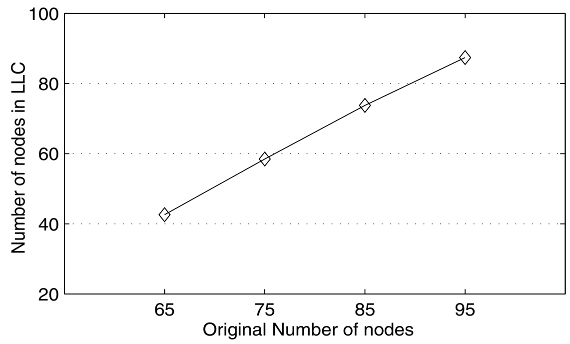

Figure 5: The average number of nodes in the LCC.

4 Empirical result

4.1 Simulation Environment

In the simulation experiments, a set S of n points (where $n \in \{65, 75, 85, 95\}$ is randomly generated in a cube of side length 100. The maximum transmission radius of each host is set to a fixed value. We first calculate all connected components in the graph. Then the largest connected component (LCC) is selected from among all the connected components to test the routing algorithms. The source and destination nodes are then randomly picked from LCC. It is suggested in [10] to consider simulations with node density per unit disk of around 5, which would correspond to the graph with average node degrees of around 4. Figure 4 illustrates a histogram of the node degrees for the graphs with the chosen simulation values n. Graphs with $n > 75$ are closest to the average node density of interest. Figure 5 displays the average number of nodes in the LCC for different n, if the number of nodes is greater than 70, the average number of nodes in the LLC is very close to the total number of nodes .

An algorithm succeeds if a path to the destination is found. To compute the packet delivery rate, this process is repeated with 100 random graphs and the percentage of successful delivers determined. To compute the average packet delivery rate, the packet delivery rate is determined 100 times and an average taken. Additionally, out of the 10,000 runs used to compute the average packet delivery rate and the average overall traffic is computed.

4.2 Observed Result

Figure 6 and Figure 7 depict the effect of the variable m in the new algorithms with different graphs densities. We found with $m = 5$ there is a trade-off between the delivery rate and the accompanying traffic. So we use this value for all our comparisons with the other algorithms. We compare the performance of the algorithms for different graphs densities in Figure 8 and Figure 9. It is immediately evident from the result given in those figures that all deterministic progress-based algorithm (Compass) has the worst delivery rate, but with almost no traffic. LAR algorithm has the best delivery rate (100%) while our algorithm $3D\_ABLAR(m)$ reaches more than 99% delivery rate but with 70% of the traffic used by LAR. G-$3D\_ABLAR(m)$-G and C-$3D\_ABLAR(m)$-C had about 95% delivery rate but with less than 35% of the traffic required by LAR algorithm.

From simulations we found that the algorithms that depend on Compass always has a small advantage over the associated ones depend on Greedy. Therefore, we just show the result of the algorithms that depend on Compass in our figures for clarity.

5 Conclusions

In this paper we propose two new position-base routing algorithms for routing in $3D$ ad-hoc networks, based on combining progress-based algorithms with restricted directional flooding algorithms. The simulation results demonstrate that these hybrid algorithms on UDG graph yield a definite improvement over all the other studied algorithms. The delivery rate is almost equivalent to the performance of the flooding algorithms but with an average 50% less routing traffic.

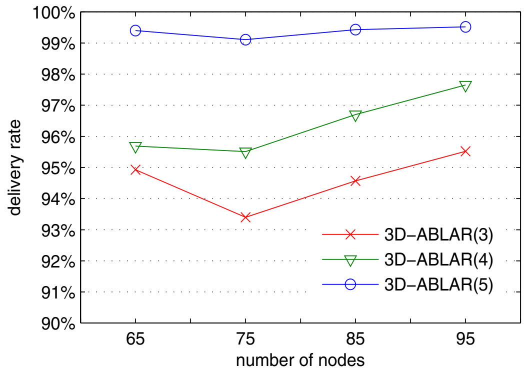

Figure 6: Effect of the variable m on the delivery rate.

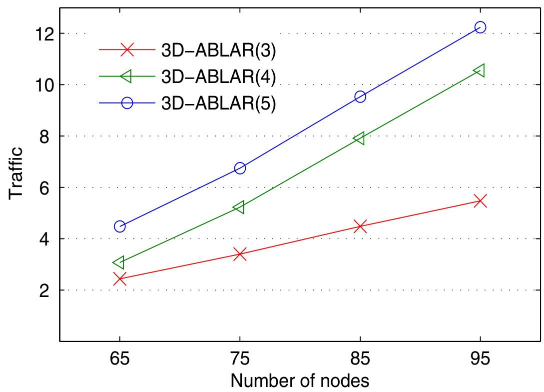

Figure 7: Effect of the variable m on the overall traffic.

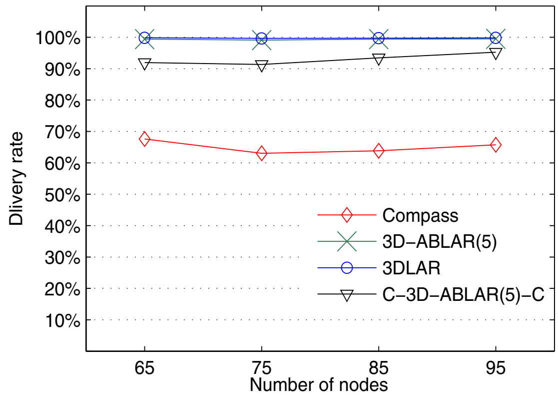

Figure 8: The packet delivery rate at different densities.

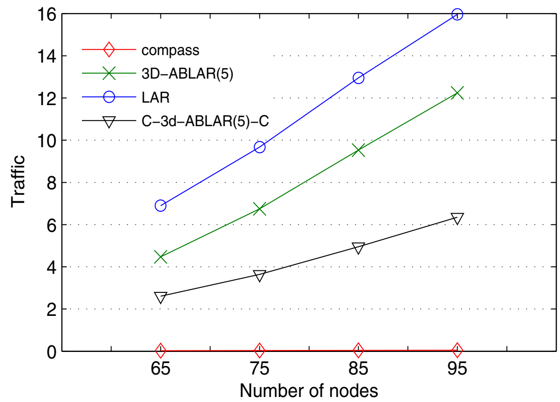

Figure 9: The average traffic at different densities.

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