Dead end Avoidance Enhanced Mechanism in GPSR

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Abstract- *Most researches of ad hoc routing are propose using geographic routing algorithms. However, the dead end situation is a critical problem when performing geographic rouging. This paper proposed a distributed dead end enhanced algorithm to reduce the risk of dead end occurrences in GPSR. The algorithm adjusts the virtual coordinate system by means of the electronics model. It and the original GPSR algorithm were evaluated using the NS2 simulator. The results show the packet delivery ratio was improved and the average number of dead end occurrences was significantly reduced.*

Keywords: Geographic routing, virtual coordinate system, mobile ad hoc networks

1. Introduction

Geographic routing algorithms are an attractive alternative to traditional ad hoc routing algorithms. Although geographic routing like Greedy Perimeter Stateless Routing (GPSR) [2] is efficient to mobile ad hoc wireless networks, it requires that nodes be aware of their physical positions to inform their neighbors. In addition, if there is a geometric hole within the network topology, which is called “dead end”, packets may be routed to a lot of redundant paths in the dead end situation. In order to reduce the risk of dead end occurrences, this paper presents a distributed routing algorithm using the electronics model. It and the original GPSR algorithm were implemented for comparison using the NS2 simulator platform [6]. The simulation results show that the packet delivery ratio was improved and the average number of dead end occurrences was significantly reduced

2. Related works

There are a lot of the works focusing on improving geographic routing performance by dead end handling in mobile wireless ad hoc networks. Here, we simply classify most of dead end handling methods into two categories: reactive and proactive, as shown in Figure 1. In reactive schemes, the recovery phase should be performed for dealing with the dead end situations [2, 9, 10]. On the other hand, proactive schemes focus on solving the dead end problems by detecting the holes within the topology in advance [3, 4 , 7, 11].

Several recovery strategies have been proposed for dealing with the dead end situations. In GPSR, when a packet reaches a dead end, a node whose neighbors are all farther away from the destination than itself, the perimeter forward is performed. If the packet reaches a location that is closer to the destination than the position where the previous greedy forwarding of the packet has failed, the greedy process is resumed.

In Greedy Embedding Spring Coordinates (GSpring) algorithm [1], the authors assume that each connective mobile node is adjacent node under the spring relaxation system. It starts from a set of initial coordinates to incrementally adjust virtual coordinates oscillate until the algorithm was convergent.

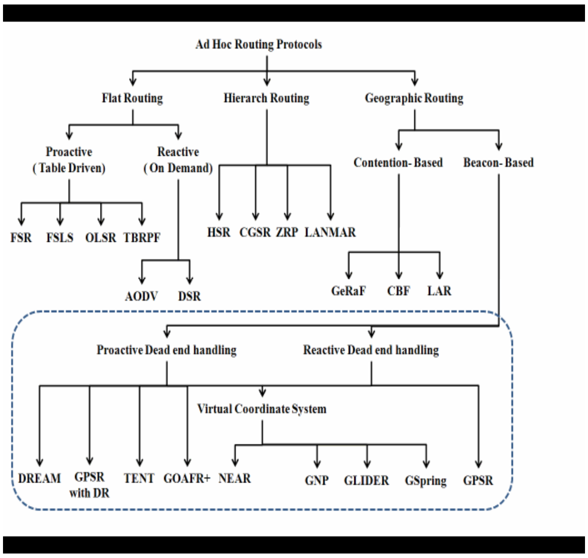

Figure 1 : Classification of Ad Hoc Routing

Finally, in GPSR with dead end reduction (DR) scheme [3], the authors define a dead end detect mechanism based on the Voronoi diagram [5]. Each node periodically constructs a local Voronoi diagram based on the information which receives from its neighbors. Every dead end segment had to be maintained among neighbors of mobile node. It will consume a lot of network resource and transmission overhead within the network.

Our scheme uses the dead end detection mechanism from DR scheme to build the virtual coordinate system automatically and to be suitable to mobile ad hoc network environments. Moreover, by applying the dead end detect mechanism to reduce the probability of dead ends during greedy forwarding, it reduces not only control overhead but also system convergent time.

3. Methodology

Although the geographic routing is more efficient than other mobile ad hoc network routings, it still has some problems, especially the dead end problem.

3.1. Construct Dead end Avoidance Enhanced mechanism

Here, we describe the concept of dead end avoidance enhanced mechanism in detail. We assume that each mobile node is an electron with positive, except for the destination node which is a negative electron. In accordance with the field theory, the packet forwarding will travel the shortest path from the source node to the destination node. For each dead end area of a node N, there is a repulsive force from the dead end area to it, as illustrated in Figure 2. The magnitude of force is the combination of two vectors. One starts with the node N and ends with one side of the dead end, and the other starts with the node N and ends with the other side of the dead end. Suppose there is a positive electron E which gives a contrary repulsive force based on the Coulomb’s law in order to make a movement in the virtual coordinate system. At the same time, if there are two or more dead end areas, we add all the repulsive forces together to pull the nodes away from the dead ends.

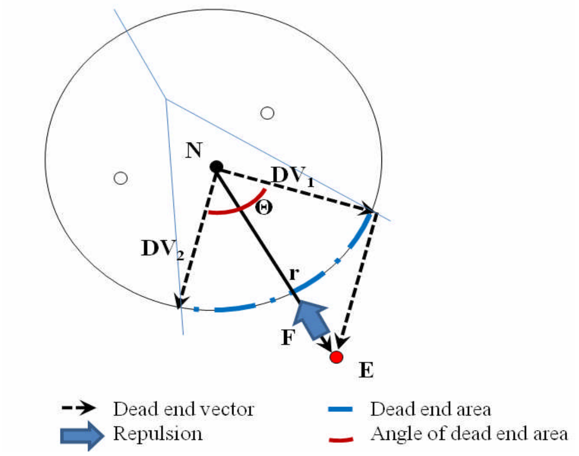

Figure 2 : Example of Dead end Avoidance Enhanced Mechanism

We assume that the repulsion magnitude is related to not only the distance from pseudo-electron to the mobile node, but also the number of neighbors. If the mobile node has the more neighbors, it has higher probability of selecting the substitute relay node. Similar to Coulomb’s law, we assume that the repulsion formula is as follows:

$$F = \frac{\alpha * N * (\Theta / 2\pi)}{r^2}$$

Where α is the constant similar to Coulomb's constant, N is the number of neighbors to represent charge of mobile node, and (Θ / 2π) propose to substitute the charge of pseudo-electron. As illustrated in Figure 2, the distance r is sum of two dead end vectors. Where r = | DV1 + DV2 |, according to law of cosines. We can define the angle Θ as follows:

$$\Theta = \cos^{-1} \left(\frac{DV_1 \cdot DV_2}{|DV_1| \, |DV_2|} \right)$$

Finally, the repulsion formula *F* is expressed as follows:

$$F = \frac{\alpha * N * \cos^{-1} \left(\frac{DV_1 \cdot DV_2}{|DV_1| \, |DV_2|} \right)}{2\pi * |DV_1 + DV_2|}$$

In the distributed network environment, each mobile node adjusts its virtual coordinate by the location information from neighbors. Thus, the nodes which locate close to hole of topology are pushed away from hole in virtual coordinate system. That means the opportunity of packet forwarding encountering the dead end situation within GPSR protocol will be decreased,

In the Dead end Avoidance Enhanced Mechanism, as illustrated in Figure 3, the nodes first detect dead end areas during exchanging beacon message with neighbors. Then, they compute each repulsive force among mobile nodes. There are several repulsive forces on mobile nodes which push them to the center of dense area. Therefore, the next relay mobile node will be far away from the dead end areas, and the selection results will be different from the original GPSR routing protocol.

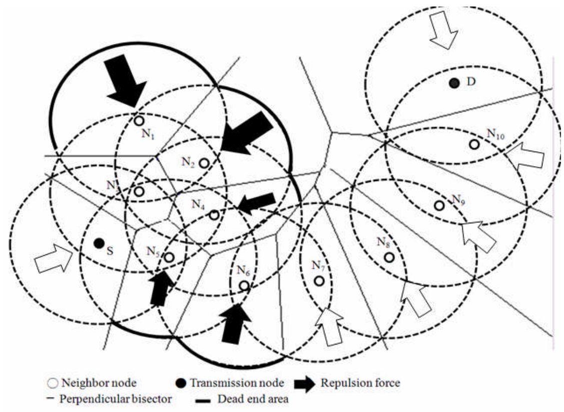

Figure 3 : Packet greedy forwarding in dead end avoidance enhanced mechanism with GPSR

Taking a global view, the Dead end Avoidance Enhanced mechanism forces the sparse network topology to become denser in the framework of entire network.

3.2. Dead end Avoidance Enhanced Mechanism Algorithm

As mentioned above, we knew the magnitude of repulsive force from pseudo electron is positively correlated to the magnitude of dead end area and number of neighbors. For simulation of our dead end avoidance enhanced algorithm, we simplify the magnitude of repulsive force as α * N * Θ/ 2π, where α is adjustable variant, and Θ is the angular magnitude of two dead end vectors. N is represented of the number of neighbors. Table.1 presents the symbols and the pseudo-code of our algorithm.

Table .1 Symbols of algorithm

Symbol	Definition
N	The number of neighbors within broadcast range
R	Broadcast radius of current node
$S = \{s_1, \ldots, s_N\}$	The set of neighbor nodes
$D = \{D_1, \ldots, D_N\}$	The set of Dead end area
Length(D)	Number of set D
α	Repulsion parameter
Θ	Angle of Dead end area
F	Repulsion force vector = α * Θ / 2π * unit vector

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For n = 0 to N within set S Then
    Find bisector vector( construct local voronoi diagram ) ;
    Find the D of set S ;
End For
Find the minimum dominate of set D ;
Sort set D by angle in counterclockwise ;
For m = 1 to Length(D) within set D Then
    Calculate the intersection I of D(0) and D(m) ;
    If( I < R )
        Combination D(0) and D(m) ;
    Else
        Calculate F and force it to virtual coordinate;
    End If
    If( Θ become clockwise )    break ;
End For
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According to the dead end avoidance enhanced algorithm, we can find that the time complexity is O(nlogn). Because there are five essential operations within the dead end avoidance enhanced mechanism, the critical operations contain sorting the set of local curves and searching the dominate point of those curves in each mobile node. Both of them can be calculated in time complexity of O(nlogn). Therefore, the time complexity does not increase too much, when the dead end avoidance enhanced mechanism is applied in GPSR.

4. Simulation

We simulate our dead end avoidance enhanced mechanism using NS2 Simulator by attaching Random Trip Mobility Model [8] to verify the correctness of our algorithm and the feasibility of our protocols. We use Random Waypoint on generalized domain to restrict two kinds of network topology. Figure 8 illustrates U-shaped and tilted E-shaped networks. They always contain geometric hole within wireless networks which cause the dead end situation when packet forwarding travels from left side to right side.

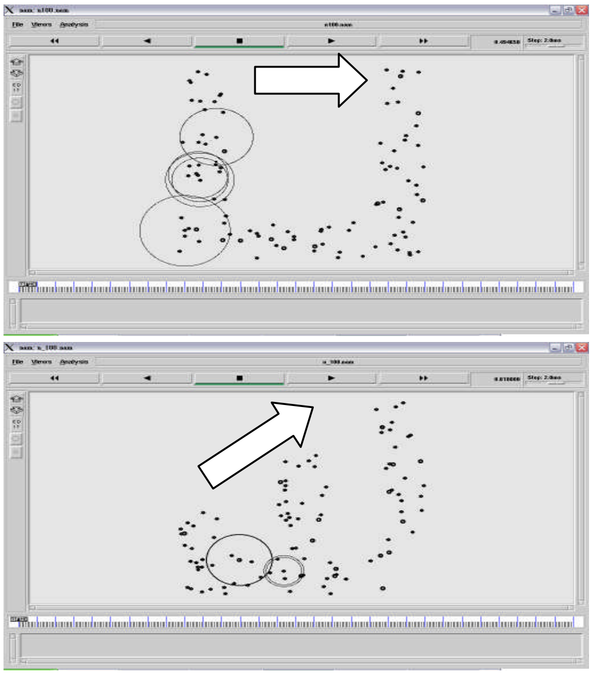

Figure 8 : U-shaped and Tilted E-shaped topology

W adopted a simple radio model. The transmission ability of the mobile nodes was provided by a 2Mbps IEEE 802.11 radio with a transmission range of 250 meters. Each simulation was run for 30 seconds and during this time the mobile nodes moved in accordance with the Random Trip Mobility model. When the node reached its destination, it immediately moved to another position without waiting a pause time. The average velocities of the nodes were 0 to 20 m/s. The compared mechanisms were described as follows:

GPSR: No dead end avoidance mechanism was applied to the original GPSR protocol.

IDA 1: Dead end Avoidance Enhanced Mechanism was applied to the original GPSR protocol with the adjustable variant α equals to one.

IDA 2: Dead end Avoidance Enhanced Mechanism was applied to the original GPSR protocol with the adjustable variant α equals to two.

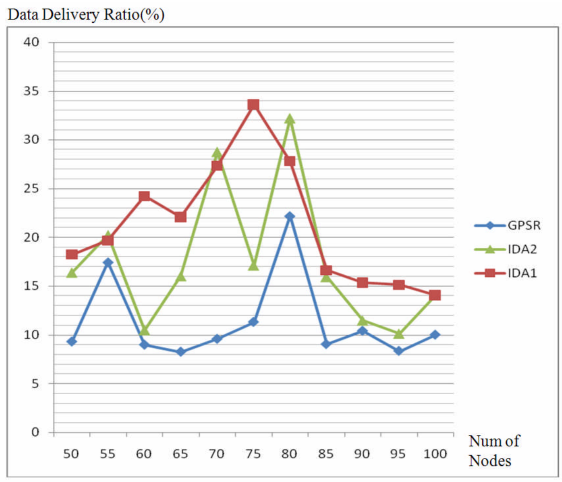

Figure 9 : Data Delivery Ratio of U-shaped network topology

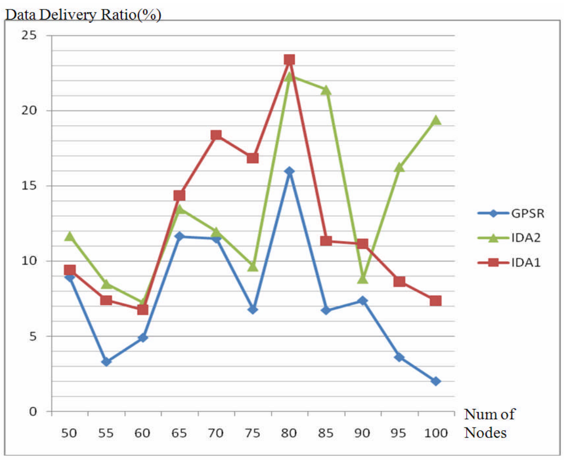

Figure 10 : Data Delivery Ratio of tilted E-shaped network topology

Figure 9 and Figure 10 display the data delivery ratio under the evaluated schemes respectively. Since fewer qualified relaying nodes existed with the original GPSR protocol, it incurred a lower data delivery ratio than GPSR with dead end avoidance mechanism. The packet delivery ratio was improved about 3 to 10 % compared with the original GPSR.

In addition, we also evaluated the average-dead-end-count during the packet delivery. Figure 11 and Figure 12 display the results respectively.

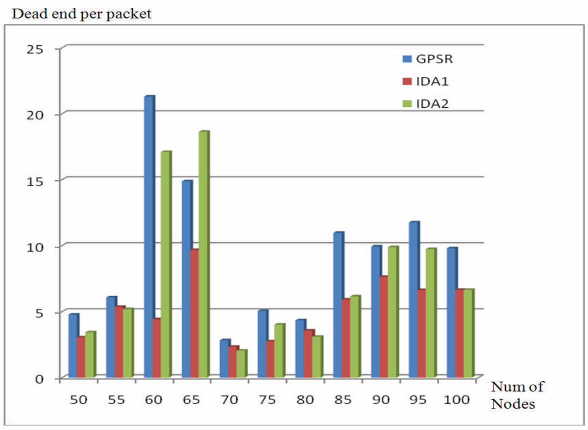

Figure 11 : AVG dead end per packet of U-shaped network topology

Where average dead-end-count is the number of packet falls into perimeter mode during forwarding divided by packet number. On average, our dead end avoidance schemes achieved about 5 average dead-end-count lower than the original GPSR.

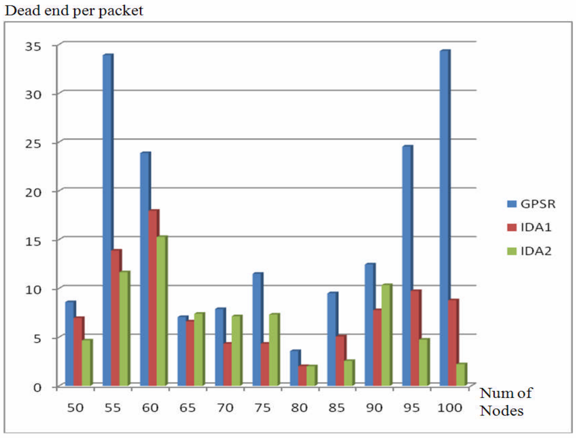

Figure 12 : AVG dead end per packet of Tilted E-shaped network topology

5. Conclusion

In this paper, we proposed a distributed algorithm to adjust the virtual coordinate system automatically, and it is easily to deploy with GPSR in mobile wireless ad hoc networks without too much overhead compared with other geographic algorithms. The simulations show that our dead end avoidance enhanced algorithm is more suitable to U-shaped-like and sparse network topology. Even though, while forwarding a packet across holes within network, our approach can't make the routing path as short as possible. However, while forwarding a packet across holes, we can reduce the risk of encountering dead end situation generated by GPSR surrounding the holes. Moreover, our approach provides a simple decision making during packet forwarding. Thus, we can obtain the much better routing performance without consuming much network resource and keeping much information within the packet header.

The Dead end Avoidance Enhanced Mechanism can improve routing performance in GPSR. However, the geometric conditions will affect our approach severely. Therefore, the detailed analysis of the formula of repulsion for routing performance is necessary to be well suited to various networks with different holes and shapes within network topology in the future.

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