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Hole detection and shape-free representation and double landmarks based geographic routing in wireless sensor networks

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Abstract

In wireless sensor networks, an important issue of geographic routing is "local minimum" problem, which is caused by a "hole" that blocks the greedy forwarding process. Existing geographic routing algorithms use perimeter routing strategies to find a long detour path when such a situation occurs. To avoid the long detour path, recent research focuses on detecting the hole in advance, then the nodes located on the boundary of the hole advertise the hole information to the nodes near the hole. Hence the long detour path can be avoided in future routing. We propose a heuristic hole detecting algorithm which identifies the hole easily and quickly and then propose a representation of hole no matter what the shape of the hole is. In addition, we quantitatively figure out the areas in the vicinity of the hole that need to be announced the hole information. With such information, a new routing scheme with two landmarks was developed. Simulation results illustrate that our approach can achieve better performance in terms of the average length and number of hops in routing paths. Simulation also shows that our approach introduces very small computational complexity.

1. Introduction

Wireless sensor networks (WMSNs) have emerged as one of the key technologies for wireless communications. They are undergoing rapid development and have inspired numerous applications [1-5] because of their advantages. A wireless sensor network consists of a collection of wireless communication nodes. Two nodes within a certain distance of each

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other can communicate directly. However, if a source node intends to send packets to a destination outside of its transmission range, it will depend on other nodes to relay the packets. Many routing protocols (e.g., DSDV [6] and AODV [7]) have been proposed to find the path from the source to the destination. The main research issue with these routing schemes is the scalability because most of them have to use flooding to find routing paths.

When the location information for nodes is available (either through GPS or using virtual coordinates [8]), routing in sensor networks can be much more efficient. Geographic routing exploits the location information and makes the routing in sensor networks scalable. The source node first acquires the location of the destination node it intends to communicate with, then forwards the packet to its neighbor closest to the destination. This process is repeated until the packet reaches the destination. A path is found via a series of independent local decisions rather than flooding. However, geographic routing suffers from the so-called local minimum phenomenon, in which a packet may get stuck at a node that fails to find a closer neighbor to the destination, even though there is a path from the source to destination in the network. This typically happens when there is a void area (or hole) that has no active nodes. In wireless sensor network, the holes are caused by various reasons [9]. For instance, the malicious nodes can jam the communication to form jamming holes. If the signal of nodes is not long enough to cover everywhere in the network plane, the coverage holes may exist. Moreover, routing holes can be formed either due to voids in node deployment or because of failure of nodes due to various reasons such as malfunctioning, or battery depletion.

To deal with the local minimum problem, Karp and Kung proposed the greedy perimeter stateless routing (GPSR) protocol, which guarantees the delivery of the packet if a path exists [10]. When a packet is stuck at a node, the protocol will route the packet around the faces of the graph to get out of the local minimum. Several approaches were proposed that are originated from the face routing. Although they can find the available routing paths, they often cause the long detour paths.

Current research is focused on developing algorithms to overcome the local minimum issue in geographic routing by finding holes prior to packet forwarding towards the holes. Scholars may use particular approaches to define and find holes in some real work applications. For instance, in a sensor network that monitors temperature in a region, if we let a sensor node mark itself as unavailable once its local temperature exceeds a threshold, then the boundary of a hole can probably be determined based on the temperatures of the nodes. Such a hole is represented as a polygon that encloses all the sensors with local temperatures higher than the threshold. Unfortunately, these algorithms are time or space consuming. Moreover, the representation of a hole is too complicated. Most recent work tries to detect a hole and the nodes located on the hole's boundary in advance [11,12]. The nodes on the boundary further advertise the hole information to some other nodes. In this way, the future routing path can be adaptive in the presence of the hole. In this paper, we introduce an algorithm of shape-free hole representation and double landmarks based geographic routing for wireless sensor networks. It focuses on defining and detecting holes in a wireless sensor network, representing holes and building routes around the holes. It is a heuristic algorithm aimed to detect a hole quickly and easily. The hole can be identified by a constant time complexity calculation. In addition, we provide a very concise format to represent a hole by representing a hole as a segment. Moreover, we develop an approach to make part of the nodes located on the hole's boundary announce to the nodes in the vicinity of the hole. We further found the best trade-off between the overhead of hole information announcement and the benefit for future routing.

2. Related work

The first geographic routing protocol is based on simple greedy forwarding. In this approach, each node forwards packets to one of its neighbors who is closest to the destination node until the packets arrive the destination. This scheme is efficient. However, it fails due to the “local minimum problem”.

To mitigate “local minimum problem”, compass routing [13] was proposed as the first face routing, in which the packet is forwarded along the face until greedy is workable in a node. However, compass routing cannot guarantee packet delivery in all geographic networks. Several routing algorithms in face routing family have been developed. By combining greedy and face routing, Karp and Kung proposed the greedy perimeter stateless routing (GPSR) algorithm [10]. It consists of the greedy forwarding mode and the perimeter forwarding mode, which is applied in the regions where the greedy forwarding does not work. An enhanced algorithm, called adaptive face routing (AFR) [14], uses an eclipse to restrict the search area during routing so that in the worst case, the total routing cost is no worse than a constant factor of the cost for the optimal route. The latest addition to the face routing family is path vector face routing (GPVFR) [15], which improves routing efficiency by exploiting local face information. The protocols in face routing family can avoid the hole. However, they often cause long detour path.

Two routing algorithms were proposed to avoid long detour path caused by hole. One is ITGR [16]. The source determines destination areas which are shaded by the holes based on previous forwarding experience. The novelty of the approach is that a single forwarding path can be used to determine an area that may cover many destination nodes. An efficient method is designed for the source to find out whether a destination node belongs to a shaded area. The source then selects an intermediate node as the tentative target and greedily forwards packets to it to avoid the long detour. Finally the intermediate target forwards the packet to the destination by greedy routing. The second is HDAR [17]. A heuristic algorithm is designed to detect a hole quickly and easily. And the hole can be identified only by calculation with constant time complexity. Then a concise representation of the hole is devised. A hole is recorded as a segment. Moreover, an approach that lets a subset of the nodes located on the hole's boundary announce the hole information to the nodes in the vicinity is developed.

A new idea [11] was proposed recently, which is to detect the hole in advance, then the nodes located on the hole