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An enhanced location-free Greedy Forward algorithm with hole bypass capability in wireless sensor networks

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HIGHLIGHTS

- We propose a new Greedy Forward algorithm for routing protocols in WSNs.
- It does not require localization information, but only the RSSI of the packets.
- It is also able to deal with nodes located near network holes.

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ABSTRACT

Greedy Forward is a technique for data routing in Wireless Sensor Networks (WSNs) in which data packets are forwarded to the node that is geographically closer to the destination node. Two main concerns can be found in routing algorithms based on this technique: first, it requires all sensor nodes to know their physical location. Second, this kind of algorithm does not work in cases when a node is located in a network 'hole', i.e., the node does not have any neighbor closer to the destination node. In this work, we propose a new Greedy Forward algorithm that can be used in routing protocols for WSNs that does not require localization of the nodes and also is able to deal with nodes located near network holes. Differently from current greedy forward algorithms, our approach uses only the Received Signal Strength Indicator (RSSI) of exchanged packets. Based on this observation, we propose the RSSR (Received Signal Strength Routing) algorithm with two variants: RSSR Election and RSSR Selection. In the RSSR Election, the next hop is dynamically elected and no packets are required for the routing task. In the RSSR Selection, neighbors exchange packets with RSSI information and the next hop of the packet is then selected from a routing table. Then, we present a novel technique for dealing with network holes even when the physical location of the nodes is unknown. This technique improves the reliability and applicability of the proposed schemes in most WSN scenarios. Our results indicate clearly that the proposed algorithms have all the benefits of a greedy forward algorithm but with better performance, better packet delivery rate and without requiring position information.

1. Introduction

Wireless sensor networks (WSNs) [1,10,36,3,46] are composed of a large number of sensor nodes used to monitor an area of interest. This type of network has become popular due to its applicability that includes several areas, such as environmental, health, industrial, domestic, agricultural, meteorological, spacial, and military applications. Several physical properties can be monitored,

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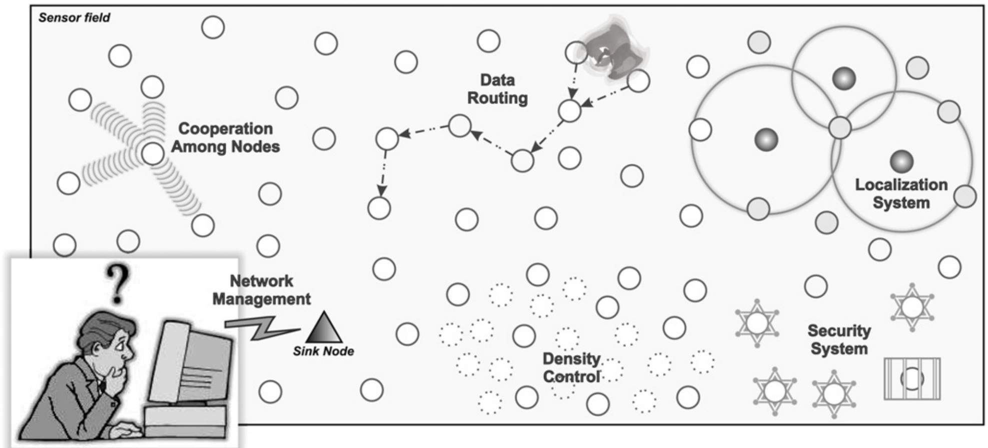

Fig. 1. Different WSN functions should work together to achieve the common goal of monitoring an area of interest.

including temperature, humidity, pressure, ambient light, and movement. Usually, the gathered information needs to be sent hop-by-hop to a central node, called sink, that is able to process the data and send the results to a Network Management and Monitoring facility using a more powerful data communication equipment.

Despite the fact that the main goal of a WSN is to monitor an area of interest, several secondary objectives, or prerequisites, need also to be achieved to reach the main objective, as shown in Fig. 1. Data routing is one of these prerequisites.

As a matter of fact, data routing toward the sink node is an important task to make viable most of the WSN applications. Therefore, different routing algorithms for WSNs have been proposed [25,16,39,21,29,43,15,2]. In particular, geographic routing algorithms [25,16,39,21,27,4,35,5,18] are closely related to the current work and have a number of advantages especially important for WSNs, such as scalability, energy-efficiency, low route discovery overhead, and low memory requirements (nodes need to store only information about their neighbors). For these reasons, geographic routing is the protocol of choice for many emerging applications in sensor networks [39]. A well-known technique used by most geographic routing algorithms is the greedy forward [4].

Greedy algorithms present advantages over other algorithmic strategies, such as simplicity and efficiency. Greedy strategies are often easier to describe and can often be implemented more efficiently when compared with other algorithms. The main drawbacks of a greedy strategy are (i) to find the right approach to design a greedy algorithm and (ii) to show that the used approach is correct. In WSN, the approach to design greedy routing algorithms uses location information of neighbor nodes to forward the packet to the node that is geographically closer to the destination node. This approach overcome the drawbacks of a greedy algorithm and is used by many geographic routing algorithms in WSNs [3]. Geographic routing is an interesting solution in terms of scalability and energy efficiency, but in order to work it requires the previous execution of a localization discovery system, which is not always available [34,38,23,8]. Furthermore, in most cases, the localization system must provide very precise position information since even small localization errors can lead to loops and low routing performance [39,35,23,28,11,33]. Another challenge in the greedy forward technique is how to deal with network holes, i.e., areas of WSNs not covered by sensor nodes [4]. To reach the sink node, in these cases, packets may need to bypass the network hole by passing thorough the nodes located near the border of the hole (see Fig. 2).

In this work, we propose a novel greedy forward algorithm, which we refer to as the RSSR (Received Signal Strength Routing) algorithm. The main idea of RSSR is to take advantage of the greater

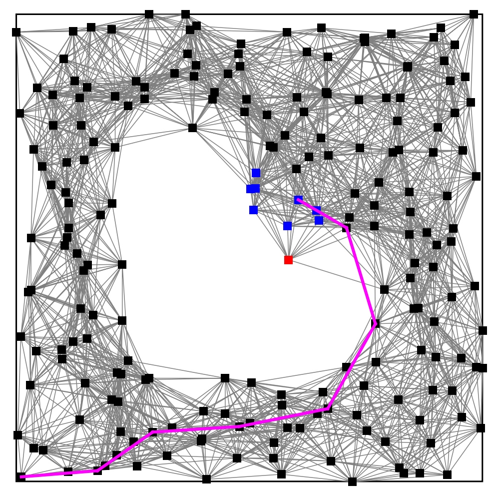

Fig. 2. A network hole, which is an area of the WSN not covered by sensor nodes. Nodes located near the border of the network hole cannot reach nodes located on the other side of the hole.

capability of the sink node and equip this special node with a more powerful communication device so it can send a query packet to all nodes of the WSN in a single hop. This query packet is a simple query message from the monitoring center asking for the sensors' gathered data such as temperature, humidity, etc. Thus, all nodes receive the same packet sent directly by the sink node using its high powerful transceptor. Then, sensor nodes can reply to the sink query by using the proposed RSSR algorithm, based on a multihop communication, since normal sensor nodes do not send a packet direct to the sink node. The same query packet sent by the sink node will reach all sensor nodes with different RSSI (Received Signal Strength Indicator) values in such a way that the most distant nodes experiment the lower signal strengths due to the propagation loss. The basic principle of RSSR is to forward the packet to the neighbor that received the query with greater signal strength, which is, in theory, the neighbor closest to the sink node. We then define two versions of the proposed approach: the RSSR Election and the RSSR Selection. In the RSSR Election, a leader election algorithm, which requires no packet exchange, chooses the next hop. In the RSSR Selection, neighbor nodes exchange RSSI information and that neighbor with the greatest RSSI is selected at each step. The proposed algorithms allow the execution of a greedy forward strategy that requires neither location information, nor virtual coordinates [38]. Also, since the positions of the nodes in a WSN are usually computed based on three or more RSSI