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Positive virtual based geographic routing for wireless sensor networks

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Abstract: Communications void in geographical routing protocols effects the performance of these routing protocols. A geographic routing protocol usually uses a greedy forwarding scheme with a recovery policy to solve the void problem. In this paper, we propose a new positive virtual position (PViP) scheme, for solving the local minimum problem. Positive virtual position of nodes are considered when selecting the next optimum neighbor node. Positive virtual position of a node is the average positions of node's itself position and all single-hop neighbor nodes that are closer to the sink than itself. Simulation results demonstrate that proposed scheme increases the success delivery rate compared with other schemes without any significant overhead.

Keywords: wireless sensor network, geographic routing, void problem, greedy forwarding, packet delivery ratio

Classification: Wireless circuits and devices

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1 Introduction

Greedy forwarding (GF) is a simple yet efficient technique employed by many routing protocols in WSNs. It is ideal to realize point-to-point routing in WSNs because packets can be delivered by only maintaining a small set of neighbors' information regardless of network size. Since the routing decisions depend, in part, on the locations of the receivers, there may be case where the packets reach local minima [1]. In other words, a node may not find any feasible nodes that are closer to the sink than itself. This problem is known as communications void in geographical routing. Fig. 1 shows the local minimum phenomenon in greedy routing for WSNs. In Fig. 1 (a), forwarding of packets toward the sink can fail at source node S, since there is no direct neighbor closer to destination than node S itself.

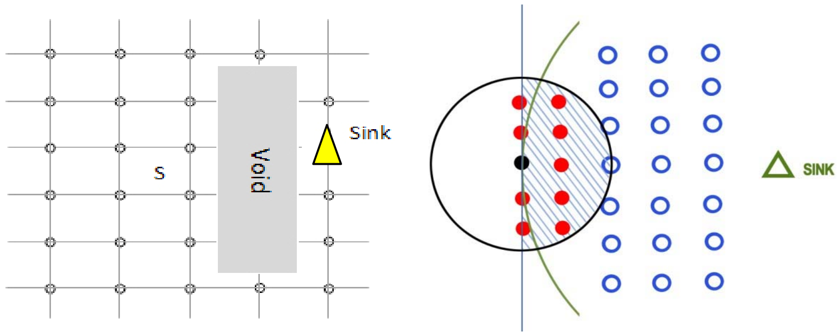

Fig. 1. (a) Void problem. (b). Positive virtual position.

Void-bypassing techniques are an important issue to be addressed in WSNs. To address void problem, we propose a new algorithm to improve success rate of packet routing. We present a geographic routing algorithm using positive virtual position. Positive virtual position is the middle position of all positive single hop neighbors of a node and node's itself coordinate. Fig. 1 (b) shows the positive single-hop neighbors of a node (red and black nodes) that we use their coordinates for calculating of node's positive virtual position.

2 Related works

Geographic routing (GR) [2, 7, 8] is attractive in WSNs because of its supervisor scalability: each node only needs to be aware of a small set of its neighbor's locations regardless of network size [6]. A geographic routing method

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usually combines a geographic greedy forwarding with a recovery mechanism to solve the local minimum problem. This problem is generally resolved through combining greedy forwarding with the well known face routing [3]. Although face routing necessitates a node to communicate with its neighbors to establish a planarized graph and construct routes to traverse around the void. This needs information exchange between the neighbors and increases the protocol overhead. Geographic routing strategies thus normally operate in two modes: Greedy forwarding mode and void handling mode [3]. In the greedy-forwarding mode, selection of a next hop node for packet forwarding is performed according to the position of the sender node, its one-hop neighbors, and the destination node. This makes geographic routing more scalable than other approaches. If an intermediate node is unable to locate a neighbor with positive progress towards the destination node, it switches to the void bypassing mode. In [3], the authors present an algorithm, called Greedy virtual position (Greedy-ViP) for void-bypassing that uses position of all node's direct neighbors coordinate for computing virtual position of nodes. Our proposed scheme improves the performance of this protocol. In [4], the authors present an algorithm, called Progress Face, which uses an additional traversal step to decide the direction of forwarding. By sending a short discovery packet along the face boundary, a concave node constructs the progress set so that, for any destination, at least one progress node is in the progress set except that some progress node exists in the neighbor set. Further, packet delivery is usually not guaranteed. In SDRCS [5], a communication void is handled inherently by grouping ID assignments and the design of forwarding metrics. Any node can be reached by the broadcast grouping message and assigned a group ID while the network is connected.

3 Positive virtual position based greedy forwarding

Virtual coordinate systems are more tolerant to routing voids [6]. In this paper, we propose a new greedy forwarding with positive virtual position greedy-PViP routing algorithm for WSNs. When a packet with destination D arrives at node A, Greedy-PViP evaluates its own positive virtual and the positive virtual positions of its positive direct neighbors. The neighbor i with the positive virtual position that is the closest to node D is selected as the next hop. The positive virtual position of a node is the average point of all its positive direct neighbors and its own coordinate. The positive virtual position of node A can be calculated as follows:

$$(x'_A, y'_A) = \left(\frac{1}{n+1}\left(x_0 + \sum_{i=1}^{n} x_{A,i}\right), \frac{1}{n+1}\left(y_0 + \sum_{i=1}^{n} y_{A,i}\right)\right) \qquad (1)$$

Where, (x_0, y_0) is coordinate of the node A and $(x_{A,i}, y_{A,i})$ is the A's positive neighbor coordinate. We assume the node A has a set of n positive direct neighbors. Each node calculates its positive according to Eq. (1) and broadcast its positive virtual position to its positive direct neighbors. The information of positive virtual position is stored on nodes themselves and

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their positive direct neighbor. To further improve the success rate of GF, we generalize PViP to higher level virtual position that considers farther nodes (neighbors of K-Hop, K $\geq$ 1). The K-th-level positive virtual position of A is calculated as follows.

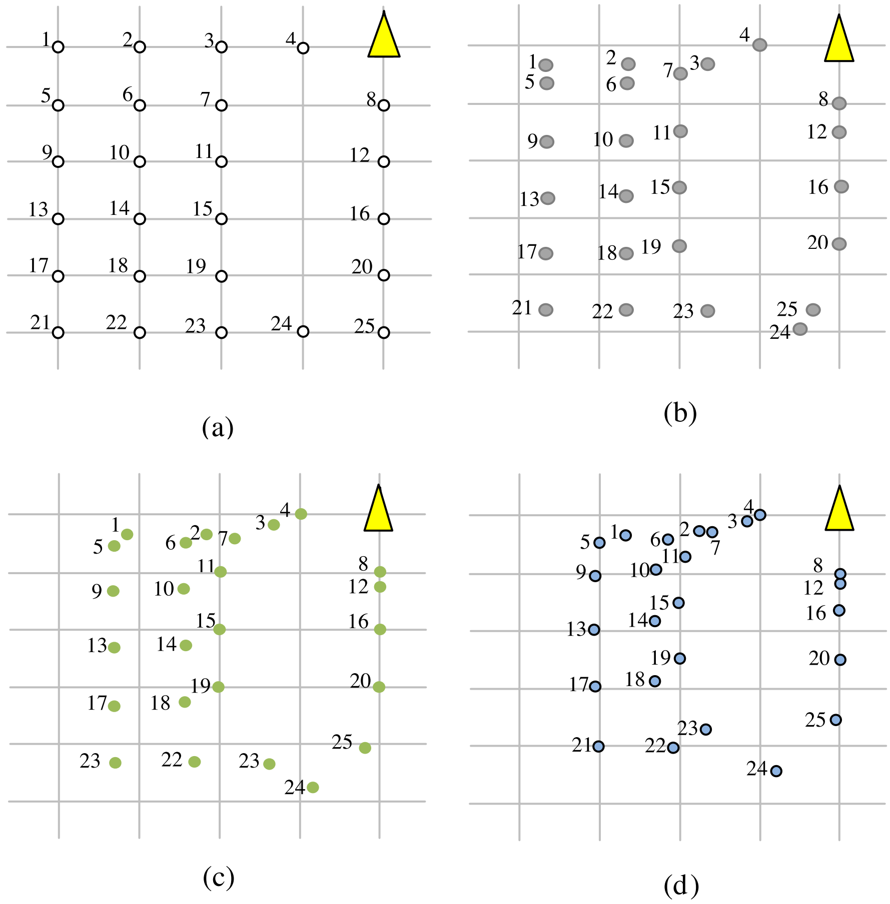
$$\text{PViP}(1)\text{: } (x', y') = \left(\frac{1}{n+1}\left(x_0 + \sum_{i=1}^{n} x_i\right), \frac{1}{n+1}\left(y_0 + \sum_{i=1}^{n} y_i\right)\right)$$

$$\text{PViP}(2)\text{: } (x'', y'') = \left(\frac{1}{n+1}\left(x'_0 + \sum_{i=1}^{n} x'_i\right), \frac{1}{n+1}\left(y'_0 + \sum_{i=1}^{n} y'_i\right)\right)$$

PViP(k):

$$(x^{(K)}, y^{(K)}) = \left(\frac{1}{n+1}\left(x_0^{(K-1)} + \sum_{i=1}^{n} x_i^{(K-1)}\right), \frac{1}{n+1}\left(y_0^{(K-1)} + \sum_{i=1}^{n} y_i^{(K-1)}\right)\right) \quad (2)$$

For K $\geq$ 1, (K + 1) rounds of information exchange between 1-hop neighbors are needed during setup. We will use PViP(K) to represent this family of algorithm, where K $\geq$ 1. Fig. 2 is an example of PViP using 4th-level positive virtual position, which demonstrates that using positive virtual position of higher level indicates better forwarding tendency in geographic routing, since it takes farther neighbors into consideration. So, we switch between different positive virtual position for solving void problem.



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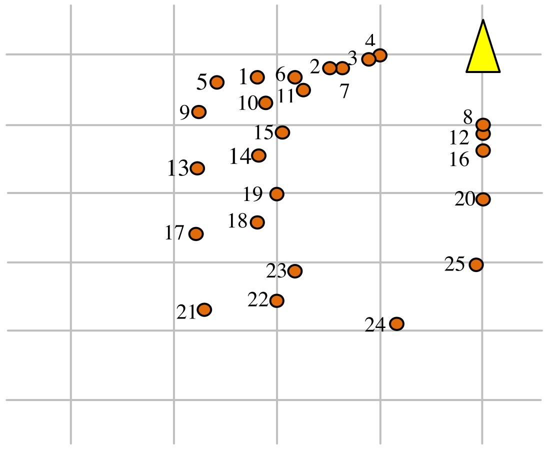

(e)

Fig. 2. Positive virtual position of nodes (a) position of sensor nodes. (b) 1st-level positivevirtual position. (c) 2nd-level. (d) 3rd-level. (e) 4th-level.

4 Performance evaluation

In this section, we evaluate the performance of greedy-PViP using matlab software. We use the following metrics to compare the performance of the simulated routing algorithms:

- **Average end-to-end delay:** This is defined as the average hop count of packets from their source to the destination [3]. Given the same success rate, small packet delay (in hops) represents better performance in terms of routing efficiency and energy consumption.
- **Average success rate:** this is defined as the percentage of successful packet delivery. When the density of deployment is low, voids appear frequently in the network [3]. This metric illustrates the ability of avoiding routing hole of greedy-PViP.
- **The number of neighbor entries stored on sensor nodes:** This metric implies the storage overhead, as well as the computational overhead due to selecting the next hop [3]. Furthermore, the control message overhead of maintaining neighbor information is also proportional to the number of entries.

We compare proposed scheme with Greey-ViP and Greedy forwarding. The simulated network is a 500 m $\times$ 500 m square plane, where sensor nodes are randomly deployed. Packets are generated with random pairs of source-destination addresses. All sensor nodes are homogeneous with 60 m radio range. The position of sink is $(x, y) = (500, 500)$. The following results are the average of 10 simulation runs. Fig. 3 compares the performance of the Greedy algorithm, Greedy-ViP(K) and Greedy-PViP(K), $K = [1, 2, 3]$. When the number of sensor nodes is small, nodes have relatively few neighbors. This leads to low success rates of the simulated algorithms. Packet routing fails

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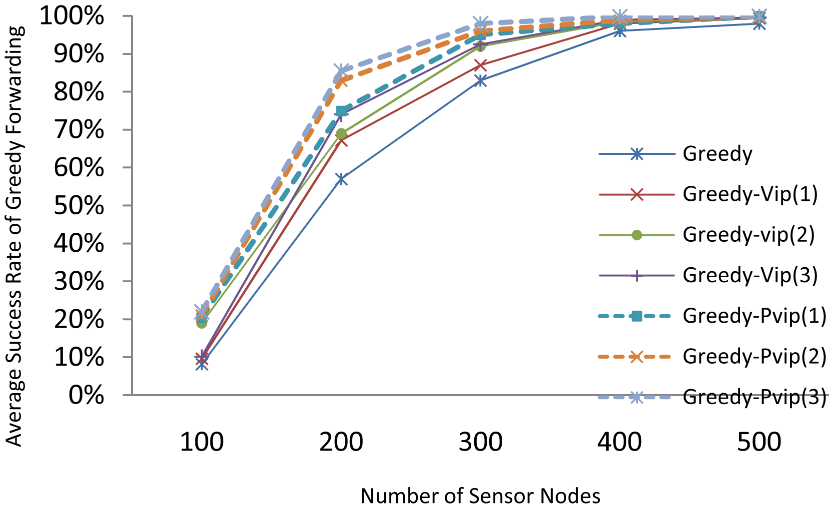
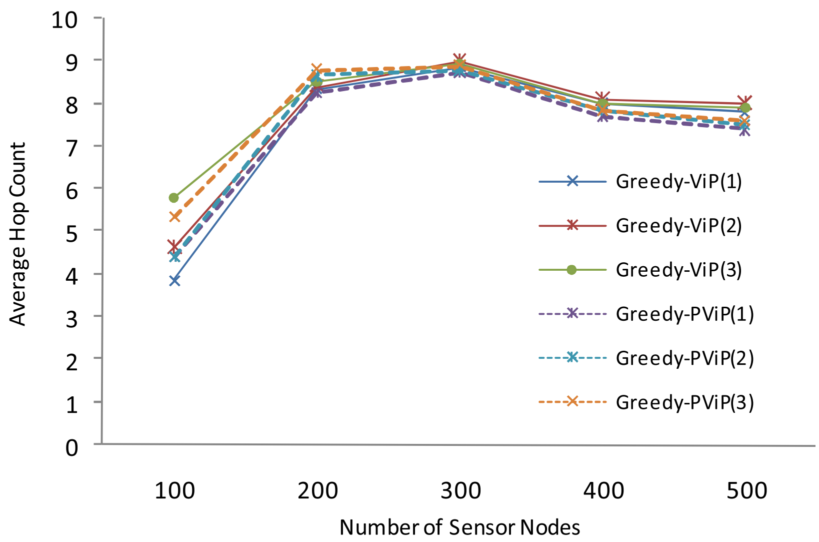
if there occurs a local minimum during forwarding. Compared to Greedy, Greedy-ViP(1) and Greedy-PViP(1) show a significant improvement of the success rate, which demonstrates protocols ability to avoid routing holes. In Fig. 3 (a), when the number of sensor nodes is small, nodes have few neighbors. This leads to low success rates of Greed-ViP and Greedy-PViP. Packet routing fails either the source and destination nodes are not connected, or there occurs a void problem. Compared to Greedy and Greedy-ViP, Greedy-PViP shows a significant improvement of the average success rate, which shows its ability to avoid routing voids. As the level of positive virtual position increases, the success rate of proposed scheme improves, since farther neighbors are considered with positive virtual position of higher levels. This is because in the calculation of virtual position and positive virtual position



(a)



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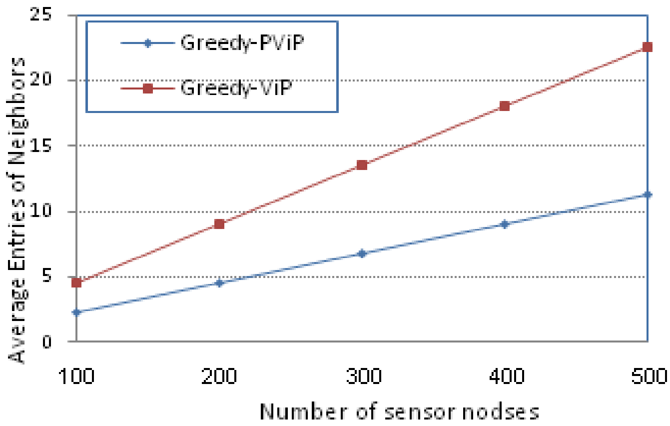

(c)

Fig. 3. Simulation results. (a) Average success rate for Greedy, Greedy-ViP(K) and Greedy-PViP(K). (b) Average delay for Greedy-ViP(K) and Greedy-PViP(K). (c) Impact of node density on overhead for Greedy-ViP and Greedy-PViP.

of higher levels, the impact of farther neighbors is becoming minor during the iterations.

Fig. 3 (b) shows the average delay of the successfully delivered packets versus varying node density. When the number of nodes is less than 300, Packet routing fails either the source and destination nodes are not connected, or there occurs a void problem. For this reason the average hop count decreased. Beacuase the success delivery rate for this range is low. When the number of nodes is greater than 300, the hop count of routing paths decreases with increasing density, due to the enriching choice of nodes to make a straight route. From Fig. 3 (b), when the density is low, the proposed algorithm (PViP(K)) shows better delay performance than Greedy-ViP(K) in the presence of routing holes, for $K = [1, 2, 3]$.

Fig. 3 (c) illustrates the control overhead of the simulated algorithms indicated by the number of neighbor entries on nodes. With improved performance in terms of success rate, PViP has the less number of neighbor entries as in ViP. This results in low storage and computational overhead of PViP. Because PViP only stores the coordinate of neighbor nodes that are closer to destination than source node. So, the storage and computational overhead of Greedy-PViP is low in comparing with Greedy-ViP.

5 Conclusion

Void problem in geographical-based routing is a challenging issue. In this paper, we present a new geographic routing algorithm named "Greedy Forwarding with positive Virtual Position (PViP)" with void-bypassing ability. Void problem can be solved with positive virtual position of sensor nodes. The greedy-PViP employs Greedy Forwarding (GF) throughout the routing processes, and inherently results in high routing efficiency as the basic GF al-

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gorithms. We evaluate proposed approach through simulations, which show that it can improve the routing quality in term of routing success rate and routing control overhead.

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