Void Less Geo-Routing for Wireless Sensor Networks

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Abstract - *Geographic wireless sensor networks use position information for Greedy routing. Greedy routing works well in dense network where as in sparse network it may fail and require the use of recovery algorithms. Recovery algorithms help the packet to get out of the communication void. However, these algorithms are generally costlier for resource constrained position based wireless sensor type networks. In the present work, we propose a Void Avoidance Algorithm (VAA); a novel idea based on virtual distance upgrading that allows wireless sensor nodes to remove all stuck nodes by transforming the routing graph and forward packet using greedy routing only without recovery algorithm. In VAA, the stuck node upgrades distance unless it finds next hop node which is closer to the destination than itself. VAA guarantees the packet delivery if there is a topologically valid path exists. NS-2 is used to evaluate the performance and correctness of VAA and compared the performance with GPSR. Simulation results show that our proposed algorithm achieves higher delivery ratio, lower energy consumption and efficient path.*

Key Words: Geo-Routing, Communication Void, Dead End, Wireless Sensor Networks.

1. Introduction

Greedy routing is a simple, efficient and scalable strategy for resource constrained position based wireless sensor type networks, where each node selects next hop node closer to the destination than itself with respect to Euclidean distance among the neighbors. However, greedy routing performs well in dense network whereas in sparse network it cannot perform well because of communication voids. Communication void is a state in which all the neighboring nodes are situated further away from the destination than the node currently holding the packet. The node where greedy multi-hop forwarding may get stuck is called a stuck node.

Many different protocols have been proposed in the literature in the past to avoid communication voids, greedy perimeter stateless routing GPSR [1] similar to Face-2 algorithm [2] constructs a planar graph and route the messages on faces that are progressively closer to the destination by using the right-hand rule when it encounters communication void and greedy forwarding is impossible. It returns back to the greedy forwarding mode when it reaches a node closer to the destination than the node where the packet entered the recovery mode. Recovery mode helps the packet to get out of the communication void. This scheme guarantees delivery if there is a path available in the original graph. However, GPSR performs well in closed void (Fig. 2) but can not perform well in the case of open void (Fig. 1).

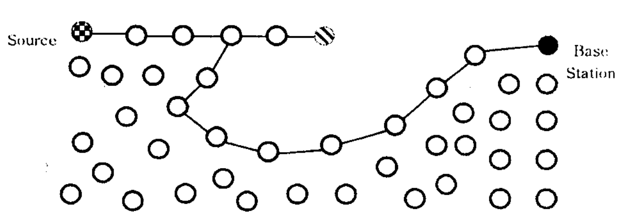


Fig.1 : Open void.

Most of the existing solutions for the communication void avoidance employ the strategy to get out of a void after getting in to the void (Fig. 1). Unlike such algorithms, we propose a heuristic algorithm that does not prevent the node to get out of a void but protect to get into a void in the first place. The primary focus of our proposed algorithm is to increase the distance to the destination virtually by stuck nodes to make themselves non-stuck nodes, so as to eliminate the communication voids and non optimal routing paths and forwards packets from sensors to base stations along efficient routes using greedy routing. After implementing our algorithm no one node remains as a stuck node in the network if it has at least one route to the destination. Further, our algorithm is completely distributed, immediately responds to node failure or topology changes, does not require planarizing underlying network, and incurs substantially less overhead. The key contribution of this work is to design the state of the art of void less wireless sensor network for geographic routing.

Our paper is organized and presented as follows: section 2: related work in the area, section 3: assumptions used in the work, section 4: five schemes of our proposed algorithm, section 5: simulations and discussions and section 6: conclusion.

2. Related Work

The existing void handling techniques can be classified into the following categories [3]. *Planar-graph-based:* Planar graph traversal algorithms come under this category. Some examples are GPSR [1], GOAFR [4], GOAFR+ [5], BLR [6], PSGR [7] etc. Theoretically, this technique guarantees packet delivery [8]. *Geometric:* Some underline geometric property of a graph is used in this category. One of the most promising works in this field is BOUNDHOLE [9]. To identify the void node it uses TENT rule. *Flooding-based*: Well known flooding technique imply to get around a void. Some examples are one-hop flooding [10], OGF [11] etc. *Cost-based*: Each node assigns cost that may be equal to Euclidean distance to the destination. Packets flow from higher cost to lower cost nodes. Examples are DUA [12], PAGER-M [13] etc. The problem with DUA is that it may produce inefficient routing paths [3] after upgrading distance because it increases cost too high. Distance upgrading in DUA cause to upgrade and downgrade distance by entire nodes along the route from the stuck node to the source node every time when any node finds itself as a stuck node. This is not efficient for small and many topological voids. Our work is closer to the DUA. In our proposed algorithm, the stuck node only upgrades distance and downgradation of distance is not required. *Heuristic Void Handling*: Alternate network [11], active exploration [14],

본 연구는 정보통신부 및 정보통신연구진흥원의 대학 IT연구센터 육성 · 지원사업의 연구결과로 수행되었음.

passive participation [15], INF [16] etc. come under this category. The problem with the protocol under this category implies that the packet delivery is usually not guaranteed. They use some extra resources or to directly exploit some inherent properties of network topology and geographic properties of void areas. *Hybrid Void Handling*: These techniques combine multiple void handling techniques together to handle voids more effectively.

Most of all of above protocols evoke void bypassing technique after encountering communication void. However, VAA prevents going inside the void by upgrading distance virtually and makes completely void less topology.

3. Assumptions

In our present work each sensor node participating in the network aware about coordinates of its geolocation. The entire sensor node knows its neighbor location via neighbor discovery protocol. Neighbors can communicate directly if they are in the transmission range of each other. All sensor nodes are static. Data packets are send from sensor to base station.

4. Void Avoidance Algorithm

As the basic idea in this algorithm is to remove all stuck nodes by transforming the routing graph and make a void-less topology. Our algorithm performs five basic functions. (i) Sending hello message from the Base Station (BS) to advertise its geolocation (ii) Send and receive information of neighbors (neighbor discovery, protocol) (iii) Virtual Distance Upgrading Algorithm (iv) Tag-Distance Upgrading Algorithm (v) Finally, after upgrading distance any sensor can forward packet using Greedy Forwarding as per the Distance Cost.

Distance Cost (DC) from each sensor node to the BS is defined as a two-tuples (TD, VD). TD is tag distance, initially set to NULL and VD is virtual distance, initially set to Euclidian distance (ED) to the base station. The precedence of DC is in lexicographic order. Our algorithm upgrades stuck nodes' ED temporally which is called VD. It restores the ED again if any node finds itself as a non-stuck node.

Our algorithm works as follows:

(a) When a node n wakes up, it exchanges its location information among its neighbors N using neighbor discovery protocol. It also receives the hello message from BS and calculates the ED.

(b) After receiving the information of the neighbors, n compares DC among neighbors and then sets logical directional links to the next hop node that is closer to the BS than itself.

(c) If any node does not have outgoing link (i.e. stuck node) the node comes one of the following categories (Fig. 5):

   (i) Concave Node: A node having more than one neighbor, but no one is closer to the BS than itself.

   (ii) Dead End Node: A node having no more than one neighbor node and also the neighbor is not closer to the destination than itself.

(d) When a node n is found itself as a concave node, it checks the neighbor table and compares its DC lexicographically and it selects the highest VD of neighbor and increase its VD to MaxVD(n_i)-1, i.e chooses the value just under that of maximum VD of neighbor.

   If the node is still concave node after upgrading its VD and/or can not upgrade its VD further, it upgrades its TD to MaxTD(n_i)-1, i.e choose the value just under that of minimum TD having neighbors. If no neighbor has a TD value greater than NULL it changes its TD value from NULL to 0 and reverse the link.

(e) Whenever a node x is found itself as a Dead End node, it changes its TG value from NULL to 0, reverse links and sends update to neighbor.

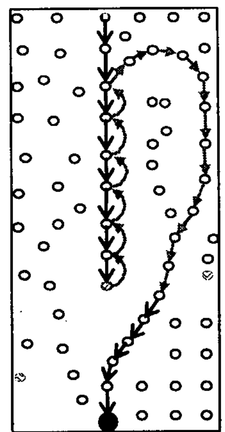


Fig. 2: Closed Void (GPSR uses perimeter routing)

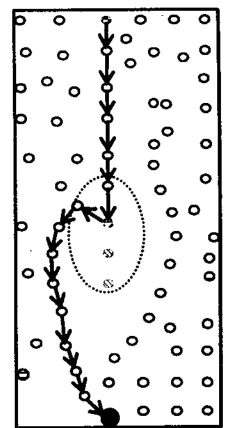


Fig. 3: Route after upgrading TD and VD.

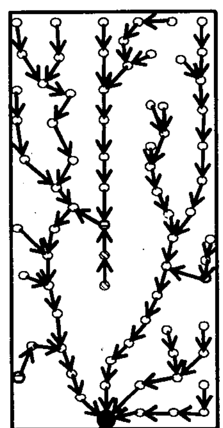


Fig. 4: Routes after applying our algorithm

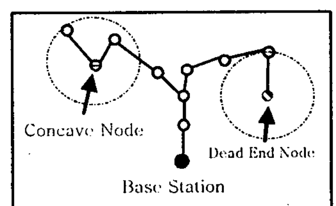
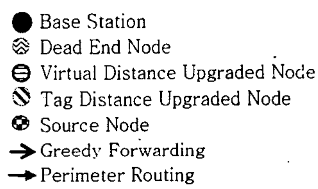


Fig.5: Concave and Dead End nodes



After upgrading the distance, the network appears as shown in Fig. 4. After a time t, the entire sensor nodes complete the setting of their next hop node towards BS and any node can start Greedy forwarding.

5. Simulations

In the present work, we used the event driven simulator ns-2 [17] for our simulations. We used GPSR [1], well accepted stateless location based routing protocol, to compare with VAA. The setup consists of a test bed of 100 nodes confined in a 500 X 600 m^2area. Range of each node is assumed to be 40m. The nodes are randomly selected for data transfer. The total setup is run for 500 s. Base station is located near the middle-left at (0, 300). We simulate 3 CBR flows originated from randomly chosen nodes across the whole networks. Each flow sents 32 byte packets at 256 bps. The key parameters of study are *path length, energy consumption, delivery ratio etc.*

When there is no void present, VAA and GPSR have similar path length (Fig. 6). It is so because VAA and GPSR both do the greedy routing when there is no void. In the casesof open void VAA outperforms GPSR significantly. The routing path in VAA is similar in the both case of closed and open void. However, GPSR can not work well in the open void.

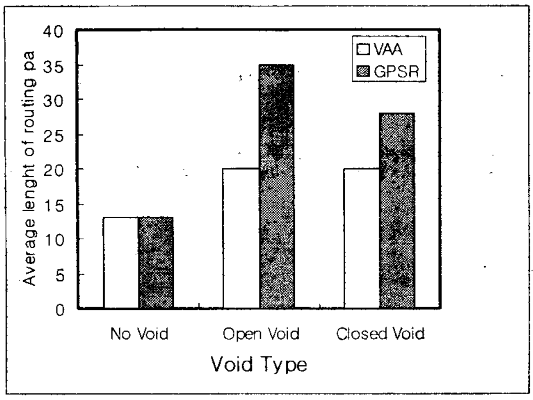


Fig. 6: Average length of routing path.

VAA has no special control packets to exchange the update information. It exchanges neighbor information via Hello message of the neighbor discovery protocol including distance update information at the same time. So, there is no much overhead. Hello message broadcast once in every five seconds.

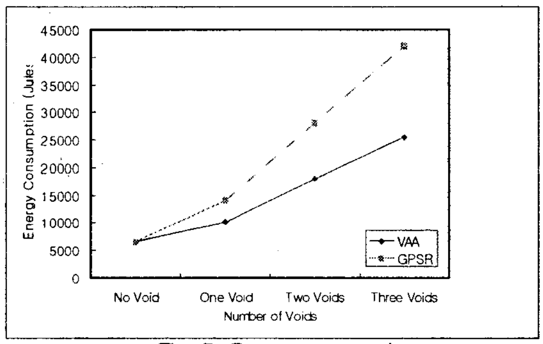


Fig. 7: Energy consumption

As GPSR follows the long route than VAA the energy expenditure ratio is obviously more in GPSR. Fig. 7 above shows the energy expenditure ratio in different cases. Energy efficiency of VAA comes from its low control overhead and low path length as shown previously.

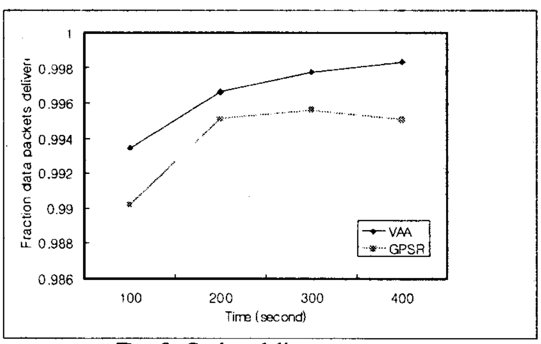


Fig. 8: Packet delivery success rate.

The packet delivery ratio is measured as the ratio of the number of data packet delivered to the base station to the number of data packet sent by the source sensors. VAA achieves an average delivery ratio of > 99%.

6. Conclusion

A new void avoidance algorithm for geo-routing that makes the wireless sensor network void-less is presented in this paper. Simulation results show that the proposed protocol can avoid the communication voids with high packet delivery success rate, low energy consumption and efficient routing path. VAA increases the distance and makes decision for the next hop node via cost function that has two touples that give efficient resolution for the dead end or concave node.

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