International Journal of Electronics Communication and Computer Engineering
Volume 4, Issue (6) NCRTCST-2013, ISSN 2249–071X

National Conference on Recent Trends in Computer Science and Technology (NCRTCST)-2013

Guarantee Delivery of Packets Using Greedy Anti-Void Routing for Wireless Sensor Networks

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Abstract **– The unreachability problem (i.e., void problem) that exists in the greedy routing algorithms has been studied for the wireless sensor networks. Some of the current research work cannot fully resolve the void problem, while there exist other schemes that can guarantee the delivery of packets with the excessive consumption of control overheads. Moreover, the hop count reduction (HCR) scheme is utilized as a short-cutting technique to reduce the routing hops by listening to the neighbor's traffic, while the intersection navigation (IN) mechanism is proposed to obtain the best rolling direction for boundary traversal with the adoption of shortest path criterion. In order to maintain the network requirement of the proposed RUT scheme under the non-UDG networks, the partial UDG construction (PUC) mechanism is proposed to transform the non-UDG into UDG setting for a portion of nodes that facilitate boundary traversal. These three schemes are incorporated within the GAR protocol to further enhance the routing performance with the reduction of communication overhead. The proofs of correctness for the GAR scheme are also given in this paper.**

Keywords **– Hop Count Reduction, Greedy Anti-Void Routing, Unit Disk Graph, Wireless Sensor Networks, Void Problem, Partial UDG Construction.**

I. Introduction

A wireless sensor network (WSN) consists of sensor nodes (SN) with wireless communication capabilities for specific sensing tasks. Due to the limited available resources, efficient design of localized multi-hop routing protocols becomes a crucial subject within the wireless sensor networks. How to guarantee delivery of packets is considered an important issue for the localized routing algorithms. The well-known greedy forwarding (GF) algorithm is considered a superior scheme with its low routing overheads. However, the void problem, which makes the GF technique unable to find its next closer hop to the destination, will cause the GF algorithm failing to guarantee the delivery of data packets. Several routing algorithms are proposed to either resolve or reduce the void problem, which can be classified into non-graph-based and graph-based schemes. In nongraph-based algorithms the intuitive schemes as proposed in construct a two-hop neighbor table for implementing the GF algorithm. The network flooding mechanism is adopted within the GRA and PSR schemes while the void problem occurs. There also exist routing protocols that adopt the backtracking method at the occurrence of the network holes. The routing schemes as proposed by ARP and LFR memorize the routing path after the void problem takes place. Moreover, other routing protocols propagate and update the information of the observed void node in order to reduce the probability of encountering the void problem. By exploiting these routing algorithms, however, the void problem can only be either 1) partially alleviated or 2) resolved with considerable routing overheads and significant converging time.

Proposed greedy anti-void routing (gar) protocol:

In this paper, a greedy anti-void routing (GAR) protocol is proposed to guarantee packet delivery with increased routing efficiency by completely resolving the void problem based on the UDG setting. The GAR protocol is designed to be a combination of both the conventional GF algorithm and the proposed rolling-ball UDG boundary traversal (RUT) scheme. The GF scheme is executed by the GAR algorithm without the occurrence of the void problem, while the RUT scheme is served as the remedy for resolving the void problem, leading to the assurance for packet delivery.

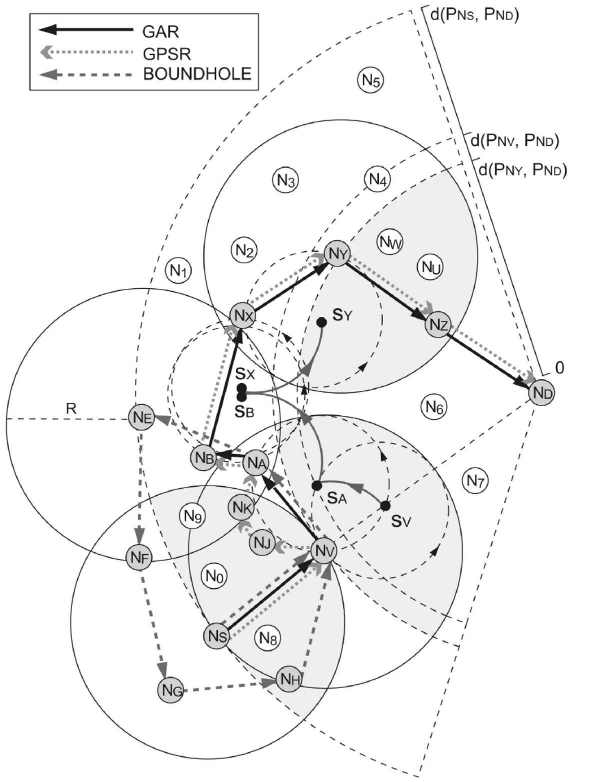

Fig.1: Example routing paths constructed by using the GAR (Greedy Routing AntiVoid), the GPSR (planar graph-based schemes) and the BOUNDHOLE algorithms under the existence of the void problem.

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Moreover, the correctness of the proposed GAR protocol is validated via the given proofs. The implementation of the GAR protocol is also explained, including that for the proposed boundary map (BM) and the indirect map searching (IMS) algorithm for the BM construction. Furthermore, the associated three additional enhanced mechanisms are also exploited, including the hop count reduction (HCR), the intersection navigation (IN), and the partial UDG construction (PUC) schemes. The HCR scheme is a short-cutting technique that acquires information by listening to one-hop neighbor's packet forwarding, while the other short-cutting method, as proposed in, requires information from two-hop neighbors that can result in excessive control packet exchanges. With the occurrence of the void node, the IN mechanism determines its rolling direction based on the criterion of smallest hop counts (HCs) for boundary traversal. Similar to the CLDP (cross-link detection protocol) method, the IN scheme acquires information over multiple hops in order to process its algorithm. However, it is required for the CLDP technique to traverse all the communication links in the networks, while the IN scheme only exploits a small portion of network links for conducting the boundary traversal. Moreover, in order to meet the network requirement for the RUT scheme under non-UDG networks, the PUC mechanism is utilized to transform the non-UDG into the UDG setting for the nodes that are adopted for boundary traversal. By adopting these three enhanced schemes, both the routing efficiency and the communication overhead of the original GAR algorithm can further be improved. The performance of the proposed GAR protocol and the version with the enhanced mechanisms (denoted as the GAR-Algorithm) is evaluated via simulations under both the UDG network for the ideal case and the non-UDG setting for realistic scenario.

The simulation results show that the GAR-based schemes can both guarantee the delivery of data packets and pertain better routing performance under the UDG network On the other hand, comparing with the other existing schemes, feasible routing performance with reduced communication overhead can be provided by the GAR-based algorithms within the non-UDG network environment. The void problem is defined as follows.

Problem 1 (void problem). The GF algorithm is exploited for packet delivery from NS to ND.

The void problem occurs while there exists a void node NV in the network such that no neighbor of NV is closer to the destination. The objective of the GAR protocol is to resolve the void problem such that the packet delivery from NS to ND can be guaranteed. Before diving into the detail formulation of the proposed GAR algorithm, an introductory example is described in order to facilitate the understanding of the GAR protocol.

As shown in Fig. 1, the data packets initiated from the source node NS to the destination node ND will arrive in NV based on the GF algorithm. The void problem occurs as NV receives the packets, which leads to the adoption of the RUT scheme as the forwarding strategy of the GAR protocol.

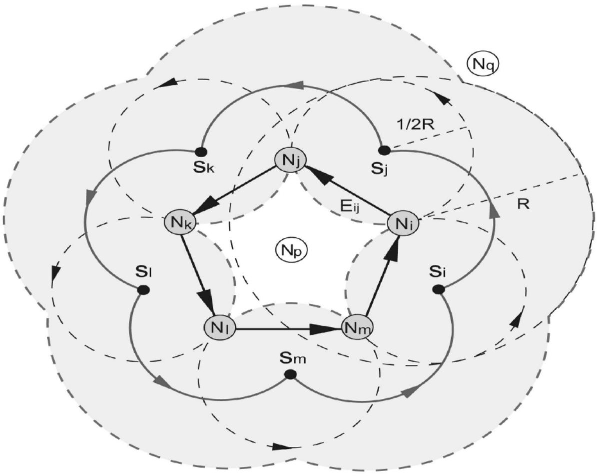

Fig.2. The proposed RUT scheme

A circle is formed by centering at SV with its radius being equal to half of the transmission range R=2. The circle is hinged at NV and starts to conduct counterclockwise rolling until an SN has been encountered by the boundary of the circle, i.e., NA, as in Fig.1. Consequently, the data packets in NV will be forwarded to the encountered node NA. Subsequently, a new equal-sized circle will be formed, which is centered at SA and hinged at node NA.

The counterclockwise rolling procedure will be proceeded in order to select the next hop node, i.e., NB in this case. Similarly, same process will be performed by other intermediate nodes (such as NB and NX) until the node NY is reached, which is considered to have a smaller distance to ND than that of NV to ND. The conventional GF scheme will be resumed at NY for delivering data packets to the destination node ND. As a consequence, the resulting path by adopting the GAR protocol becomes {NS; NV; NA; NB;NX;NY;NZ;ND}. In the following sections, the formal description of the RUT scheme will be described in below, while the detail of the GAR algorithm is explained in below. The proofs of correctness of the GAR protocol are given in Section.

II. Proposed Rolling-Ball UDG Boundary Traversal (RUT) Scheme

The RUT scheme is adopted to solve the boundary finding problem, and the combination of the GF and the RUT scheme (i.e., the GAR protocol) can resolve the void problem, leading to the guaranteed packet delivery. The definition of boundary and the problem statement are described as follows.

Definition 1 (boundary): If there exists a set B subset of N such that 1) the nodes in B form a simple unidirectional ring and 2) the nodes located on and inside the ring are disconnected with those outside of the ring, B

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is denoted as the boundary set and the unidirectional ring is called a boundary.

Definition 2 (Starting Point): As shown in Fig. 2, each node Ni can verify if there exists an SP since the rolling ball RBN(Si,R/2) bounded by the transmission range of Ni. According to Definition 2, the SPs should be located on the circle centered at PNi with a radius of R/2.All the SPs will result in the red solid flower-shaped arcs, as in Fig. 2. It is noticed that there should always exist an SP, while the void problem occurs within the network, which will be explained in Section 3.2. At this initial phase, the location si can be selected as the SP for the RUT scheme.

Boundary Traversal Phase: Given Si as the SP associated with its RBN (Si,R/2) hinged at Ni, either the counter clockwise or clockwise rolling direction can be utilized. As shown in Fig. 2, RBN (Si,R/2) is rolled counterclockwise until the next SN is reached (i.e., Nj in Fig. 2). The Unidirectional edge Eij=(PNi, PNj) can therefore be constructed. A new SP and the corresponding rolling ball hinged at Nj (i.e., sj and RBN (Si,R/2)) will be assigned, and consequently, the same procedure can be conducted continuously.

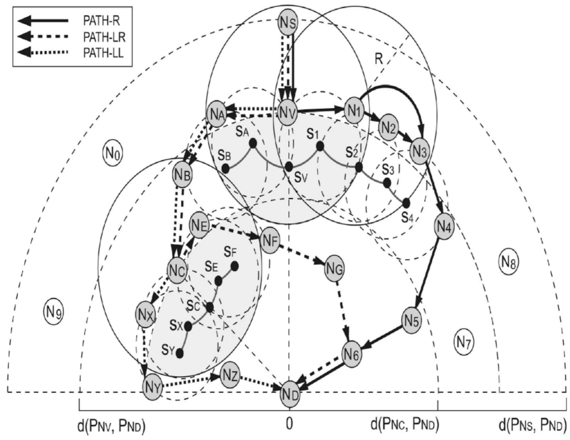
Termination Phase: The termination condition for the RUT scheme happens while the first unidirectional edge is revisited. As shown in Fig. 2, the RUT scheme will be terminated if the edge Eij is visited again after the edges Eij, Ejk, Ekl, Elm, and Emi are traversed. The boundary set initiated from Ni can therefore be obtain as B={Ni,Nj,Nk,Nl,Nm}

Concept of Boundary Map: In order to resolve the implementation issue of the boundary traversal as mentioned above, a new parameter called BM (denoted as MNi for each Ni) is introduced in this section. Moreover, the BM MNi is mainly derived from the one-hop neighbor table TNi via the IMS method, as shown in Algorithm 1.

Instead of diving into the IMS algorithm, the functionality of MNi is first explained. The purpose of the BM MNi is to provide a set of direct mappings between the input SNs and their corresponding output SNs with respect to Ni. Based on Theorem 1, the two adjacent communication links formed by the input node, the node Ni, and the corresponding output node within the RUT scheme consist part of the network boundary. Therefore, the direct mappings between the input SNs and their corresponding output SNs with respect to Ni lead so called BM.

III. Enhanced Mechanisms For Proposed GAR Protocol

In order to enhance the routing efficiency of the proposed GAR protocol, three mechanisms are proposed in this section, i.e., the HCR, the IN, and the PUC schemes. These three mechanisms are described as follows:



Hop Count Reduction (HCR) Mechanism:

Hop Count Reduction (HCR) Mechanism Based on the rolling-ball traversal within the RUT scheme, the selected next-hop nodes may not be optimal by considering the minimal HC criterion. Excessive routing delay associated with power consumption can occur if additional hop nodes are traversed by adopting the RUT scheme. As shown in Fig. 5, the void node NV starts the RUT scheme by selecting N1 as its next hop node with the LIU AND FENG: The HCR and the IN mechanisms. Counterclockwise rolling direction, while N2 and N3 are continuously chosen as the next hop nodes. Considering the case that N3 is located within the same transmission range of N1, it is apparently to observe that the packets can directly be transmitted from N1 to N3. Excessive communication waste can be preserved without conducting the rerouting process to N2. Moreover, the boundary set B forms a simple unidirectional ring based on Theorem 1,which indicates that a node's next-hop SN can be uniquely determined if its previous hop SN is already specified.if NV is the previous node of N1,N1's next hop node N2 is uniquely determined, i.e., the transmission sequences of every three nodes (e.g., fNV ! N1 ! N2g or fN1 !N2 ! N3g) can be uniquely defined. According to the concept as stated above, the HCR mechanism is to acquire the information of the next few hops of neighbors under the RUT scheme by listening to the same forwarded packet. It is also worthwhile to notice that the listening process does not incur additional transmission of control packets. As shown in Fig. 5, N1 chooses N2 as its next-hop node for packet forwarding. while N2 selects N3 as the next hop node in the same manner. Under the broadcast nature, N1 will listen to the same packets in the forwarding process from N2 to N3. By adopting the HCR mechanism, N1 will therefore select N3 as its next hop node instead of choosing N2 while adopting the original RUT scheme. Consequently, N1 will initiate its packet forwarding process to N3 directly by informing the RUT scheme that the rerouting via N2 can be skipped.

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Performance evaluation module: The performance of the proposed GAR algorithm is evaluated and compared with other existing localized schemes via simulations, including the reference GF algorithm, the planar graph-based GPSR and GOAFR++ schemes, and the UDG-based BOUNDHOLE algorithm. The following five performance metrics are utilized in the simulations for performance comparison:

Packet Arrival Rate: The ratio of the number of received data packets to the number of total datapackets sent by the source.

Average End-to-End Delay: The average time elapsed for delivering a data packet within a successful transmission.

Path Efficiency: The ratio of the number of total hop counts within the entire routing path over the number of hop counts for the shortest path.

Communication Overhead: The average number of transmitted control bytes per second, including both the data packet header and the control packets.

Energy Consumption: The energy consumptionfor the entire network, including transmission energy consumption for both the data and control packets.

IV. Conclusions

In this paper, a UDG based GAR protocol is proposed to solve the some void problems by using conventional GF algorithm. The RUT scheme is adopted within the GAR protocol solve by using the boundary finding problem, results can be delivery of data packets under UDG networks. The correctness of the RUT scheme and the GAR algorithm is properly proven. The performance of GAR Protocol is evaluated and compared with existing localized routing algorithms via simulations. The simulation study shows that the proposed GAR algorithm can guarantee the delivery of data packets with reduced communication overhead under different network scenarios.

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