Enhanced Greedy Routing with Anti-Void Traversal for Wireless Sensor Networks

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***Abstract* -- In this paper the solution to the void problem is taken up as the issue. This situation which exists in the currently existing greedy routing algorithms has been studied for the wireless sensor networks. The GAR protocol is a new protocol proposed here to guarantee the delivery of packets and excessive consumption of control overheads is resolved.**

This protocol is a combination of the GF algorithm and the RUT scheme. To enhance this protocol's functionality we go in for three mechanisms that can also be implemented in this project. The hop count reduction (HCR) scheme is utilized as a short-cutting technique to reduce the routing hops by listening to the neighbour's traffic, the intersection navigation (IN) mechanism is proposed to obtain the best rolling direction for boundary traversal with the adoption of shortest path criterion. These three schemes are incorporated within the GAR protocol to further enhance the routing performance with reduced communication overhead. The proofs of correctness for the GAR scheme are also given in this paper.

***Keywords*- Greedy routing, void problem, unit disk graph, localized algorithm, wireless sensor network.**

I. INTRODUCTION

Smart environments represent the next evolutionary development step in building, utilities, industrial, home, shipboard, and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world.

Sensory data comes from multiple sensors of different modalities in distributed locations. The smart environment needs information about its surroundings as well as about its internal workings; this is captured in biological systems by the distinction between exteroceptors and proprioceptors. The complexity of wireless sensor networks, which generally consist of a data acquisition network and a data distribution network, monitored and controlled by a management centre. The plethora of available technologies makes even the selection of components difficult, let alone the design of a consistent, reliable, robust overall system. The study of wireless sensor networks is challenging in that it requires an enormous breadth of knowledge from an enormous variety of disciplines. In this chapter we outline communication networks, wireless sensor networks and smart sensors, physical transduction principles, commercially available wireless sensor systems, self-organization, signal processing and decision-making, and finally some concepts for home automation.

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 the nongraph- based algorithms [3], [4], [5], [6], [7], [8], [9], [10], [11], the intuitive schemes as proposed in [3] construct a two-hop neighbor table for implementing the GF algorithm. The network flooding mechanism is adopted within the GRA [4] 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 (such as GEDIR, [3], DFS [5], and SPEED [6]). The routing schemes as proposed by ARP and LFR memorize the routing path after the void problem takes place. Moreover, other routing protocols (such as PAGER [7], NEAR [8], DUA [9], INF [10], and YAGR [11]) 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. The Gabriel graph (GG) and the relative neighborhood graph (RNG) are the two commonly used localized planarization techniques that abandon some communication links from the UDG for achieving the planar graph. Nevertheless, the usage of the GG and RNG a graph has significant pitfalls due to the removal of critical communication links, leading to longer routing paths to the destination.

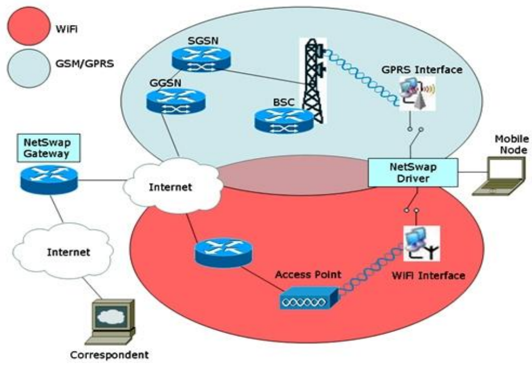

Fig2 : GPRS and WiFi Interface

In fig2 the working mechanism for GPSR and WiFi interface has been shown. The representative planar graph-based GPSR scheme can not forward the packets from NV to NA directly since both the GG and the RNG planarization rules abandon the communication link from NV to NA. Considering the GG planarization rule for example, the communication link from NV.

II. LOCALIZED ALGORITHMS

The key idea is to request and process data only at the node which requested a task and some limited number of nodes that are geographically close.

A generic localized algorithm for solving optimization problems in wireless ad-hoc networks. The technique has five components:

i. Data acquisition mechanism
ii. Optimization mechanism
iii. Search expansion rules
iv. Bounding conditions
v. Termination rules

The data acquisition mechanism facilitates which sensed data is obtained from which node. The optimization mechanism provides a partial or complete solution to the targeted task. Search expansion rules indicate which nodes are best to contact next. Bounding conditions indicate which nodes should not be considered further, since information that they have is irrelevant for the final solution.

Finally, termination criteria indicate when search expansion and optimization mechanism can be halted. The idea is to request and process data only locally and only from nodes who are likely to contribute to both final solution as well as to provide good bounds to determine non-promising search directions. It is important to note that initialization may start from a single point (as in the case of minimal exposure path coverage) or multiple points (as in the case of location)

A. Algorithm to find out the shortest path

```
 Initialization:
  N={A}
  for all nodes v
    if v adjacent to A
      then D(v)=c(A,v)
      else D(v)=inft y
 find w not in N such that D(w) is a minimum
  add w to N
  update D(v) for all v adjacent to w and not in N:
     D(v)=min (D(v),D(w)+c(w,v))
/*new cost to v is either old cost to v or known
Shortest path cost to w plus cost from w to v */
```

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.

B. Greedy Forwarding (GF) algorithm:

A greedy algorithm is any algorithm that follows the problem solving meta heuristic of making the locally optimal choice at each stage with the hope of finding the global optimum.

C. Applications of the GF algorithm

Greedy algorithms mostly (but not always) fail to find the globally optimal solution, because they usually do not operate exhaustively on all the data. They can make commitments to certain choices too early which prevent them from finding the best overall solution later. For example, all known *greedy coloring* algorithms for the *graph coloring problem* and all other *NP-complete* problems do not consistently find optimum solutions. Nevertheless, they are useful because they are quick to think up and often give good approximations to the optimum

III. CLASSES OF NETWORKS FOR GPSR ALGORITHMS

GPSR will allow the building of networks that cannot scale using prior routing algorithms for wired and wireless networks. Such classes of networks include:

- Rooftop networks: fixed, dense deployment of vast numbers of nodes
- Ad-hoc networks: mobile, varying density, no fixed infrastructure
- Sensor networks: mobile, potentially great density, vast numbers of nodes, impoverished per-node resources

D. Greedy Other Adaptive Face Routing (GOAFR) algorithm:

GOAFR combines the Greedy Routing and OAFR, such that it is both average-case efficient and worst case optimal. In general GOAFR does Greedy Routing as long as possible and only uses OAFR to tackle the local minima. The details of GOAFR are as follows. GOAFR also has a bounding ellipse.

Initially, the length of the major axis is $c = 2|st|$.

The algorithm starts by Greedy Routing inside the bounding ellipse. There are two cases to interrupt a Greedy Phase.

1. The bounding ellipse is too small, i.e. the current node does have neighbours closer to *t*, but all such neighbours lie outside the bounding ellipse.
2. The current node is indeed a local minimum, i.e. it has no neighbour closer to *t* in the entire graph.

In the former case, we double the length of *c*, and continue the Greedy Routing inside the larger ellipse. In the latter case, we have to use OAFR. An OAFR Phase of GOAFR only traverses one face boundary to get around the local minimum. After that, GOAFR returns to the Greedy Routing immediately. Here in *fig3* the flow of the IMS is shown.

The details of an OAFR Phase are the same as the original OAFR algorithm. It tries to find the best possible node inside the bounding ellipse and doubles the major axis when necessary. Note that the bounding ellipse never shrinks after GOAFR returns to the Greedy Routing.

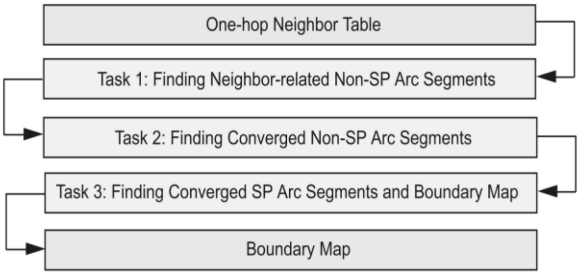

Fig3 : The process flow of the IMS algorithm.

IV. ENHANCED MECHANISMS FOR PROPOSED GAR PROTOCOL

Basically there are some mechanisms which can be implemented or incorporated in this GAR protocol to make this GAR work even better in the network. In the Figure2 mechanism is explained. Those 3 mechanisms are

- Hop count Reduction
- Intersection Navigation
- Partial UDG construction.

A. Mechanism 1 – Hop Count Reduction (HCR):

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. 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.

B. Algorithm to implement the link state routing

```
Initialization:
  for all adjacent nodes v :
    $D^X(*,v)$=infty /* the * operator means "for all rows"*/
    $D^X(v,v)=c(X,v)$
  for all destinations,y
    send min $_wD^X(y,w)$ to each neighbor /* w over all X's neighbors */
      Wait (until I see a link cost change to neighbor V
            or until I receive update from neighbor V)
    if(c(X,V) changes by d)
      /* change cost to all dest's via neighbor v by d */
      for all destinations y: $D^X(y,V) = D^X(y,V)+d$
    else if (update received from V wrt destination Y)
      /* shortest path from V to some Y has changed */
        V has sent a new value for its min $_wDV(Y,w)$*/
      /* call this received new value is "newval" */
        for the single destination y: $D(Y,V)=c(X,V)+newval$
        if we have a new min $_wD^X(y,w)$ for any destination Y
        send new value of min $_wD^X(y,w)$ to all neighbors
  forever
```

C. Mechanism 2 – Intersection Navigation (IN):

The IN mechanism is utilized to determine the rolling direction in the RUT scheme while the void problem occurs. It is noticed that the selection of rolling direction (i.e., either counterclockwise or clockwise) does not influence the correctness of the proposed RUT scheme to solve Boundary Traversal problem as in Theorem 1. However, the routing efficiency may be severely degraded if a comparably longer routing path is selected at the occurrence of a void node. The primary benefit of the IN scheme is to choose a feasible rolling direction while a void node is encountered. Consequently, smaller rerouting HCs and packet transmission delay can be achieved. Considerable routing efficiency can be preserved as a shorter routing path is selected by adopting the IN mechanism.

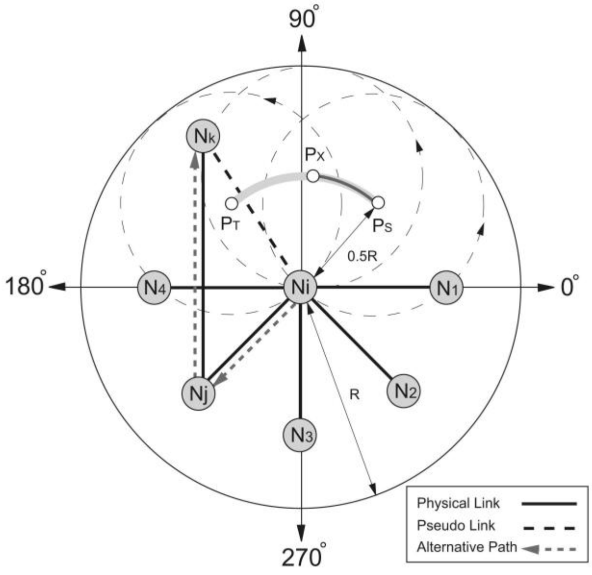

Figure 2: The PUC mechanism

D. Mechanism 3 –Partial UDG construction.

The PUC mechanism is targeted to recover the UDG linkage of the boundary node Ni within a non-UDG network. The boundary nodes within the proposed GAR protocol are defined as the SNs that are utilized to handle the packet delivery after encountering the void problem. As node Ni is considered a boundary node since the converged SP arc segment $S^{SP}_{Ni}(P_S, P_T)$ exists after Ni conducts the proposed IMS algorithm by the input of the current one-hop neighbors *{N1;N2;N3;N4;Nj}*. It is noted that the boundary nodes consist of a portion of the network SNs. Therefore, conducting the PUC mechanism only by the boundary nodes can conserve network resources than most of the existing flooding-based schemes that require information from all the network nodes.

The protocol defined with all these enhancements is called as the GAR – E (i.e. The Enhanced GAR) protocol. This protocol thus stated with all these mechanisms works more appropriate and more effectively than the GAR protocol.

V. PERFORMANCE EVALUATION

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. It is noted that the GPSR and GOAFR++ schemes that adopt the GG planarization technique to planarize the network graph are represented as the GPSR(GG) and GOAFR++(GG) algorithms, while the variants of these two schemes with the CLDP planarization algorithm are denoted as the GPSR(CLDP) and GOAFR++(CLDP) protocols. The random topology is considered in both two different types of network simulations as follows: 1) the pure UDG network as the ideal case, and 2) the non-UDG network for realistic network environment. Furthermore, the GAR protocol with the enhanced mechanisms (i.e., the HCR, the IN, and the PUC schemes) is also implemented, which is denoted as the GAR-E algorithm. The simulations are conducted in the network simulator (NS-2, [31]) with wireless extension, using the IEEE 802.11 DCF as the MAC protocol. The parameters utilized in the simulations are listed, as shown in Table 2, and the following five performance metrics are utilized in the simulations for performance comparison:

1.Packet arrival rate - The ratio of the number of received data packets to the number of total data packets sent by the source.
2.Average end-to-end delay - The average time elapsed for delivering a data packet within a successful transmission.
3.Path efficiency - The ratio of the number of total HCs within the entire routing path over the number of HCs for the shortest path.
4.Communication overhead - The average number of transmitted control bytes per second, including both the data packet header and the control packets.
5. Energy consumption - The energy consumption for the entire network, including transmission energy consumption for both the data and control packets under the bit rate of 11 megabits per second (Mbps) and the transmitting power of 15 dBm for each SN.

TABLE 2
SIMULATION PARAMETERS

Parameter Type	Parameter Value
Network Area	1000 x 800 m^2
Simulation Time	150 sec
Transmission Range	250 m
Traffic Type	Constant Bit Rate (CBR)
Data Rate	12 Kbps
Size of Data Packets	512 Bytes
Node Degree	17.5
Communication Pairs	3
Number of Void Blocks	3
Void Width	300 m
Void Height	150, 225, 300, 375, 450 m

The simulations of the performance metrics versus the void height, i.e., the height of each void block, are conducted and compared with other baseline protocols under the UDG and the non-UDG networks. The non-UDG network is obtained by randomly removing some of the communication links within the original UDG network for violating the properties of the UDG setting.

VI. CONCLUSION

In this paper, a UDG-based GAR protocol is proposed to resolve the void problem incurred by the conventional GF algorithm. The RUT scheme is adopted within the GAR protocol to solve the boundary finding problem, which results in guaranteed delivery of data packets under the UDG networks. The BM and the IMS are also proposed to conquer the computational problem of the rolling mechanism in the RUT scheme, forming the direct mappings between the input/output nodes. The correctness of the RUT scheme and the GAR algorithm is properly proven.

The HCR and the IN mechanisms are proposed as the delay-reducing schemes for the GAR algorithm, while the PUC mechanism is utilized to generate the required topology for the RUT scheme under the non-UDG Networks. All these enhanced mechanisms associated with the GAR protocol are proposed as the enhanced GAR (GAR-E) algorithm that inherits the merit of guaranteed delivery. The performance of both the GAR and GAR-E Protocols is evaluated and compared with existing localized routing algorithms via simulations. The simulation study shows that the proposed GAR and GAR-E algorithms can guarantee the delivery of data packets

Under the UDG network, while the GAR-E scheme further improves the routing performance with reduced communication overhead under different network scenarios.

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