2-Hop Neighbour Information Based Energy Efficient Multi-Parameter Geographic Routing Algorithm

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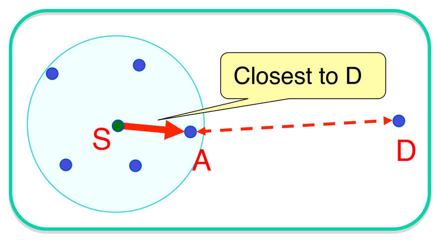
Abstract

Geographic routing is highly desirable as it is stateless, efficient, scalable, and has low overhead. Presented here is a new 2-hop neighbour information based Multi-Parameter Geographic Routing Algorithm to achieve effective energy balancing throughout the network, while preventing the deadlock/"routing void" situations by predicting and avoiding the "local maxima" nodes. The network parameters considered are Distance from Destination, Node Connectivity, Link Quality and Node Residual Energy to formulate a routing metric used for a multi-objective geographic routing algorithm. One major contribution of the proposed scheme is the elimination of secondary routing scheme, supplementing it by the reverse-progress-mode of the proposed algorithm. Furthermore, employing Link Quality in routing metric ensures only high packet-success-probability links are chosen. The simulation results using NS-2 illustrate the advantages of the proposed scheme.

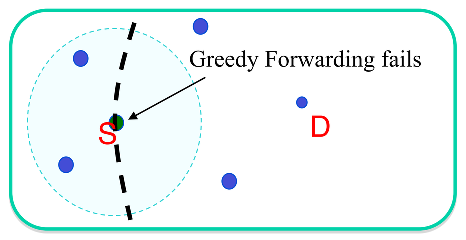
Background – Geographic Routing

Use node location information for routing
Combination of 2 Routing Schemes
•Primary – Greedy Forwarding
•Secondary – Perimeter Routing



Greedy Forwarding

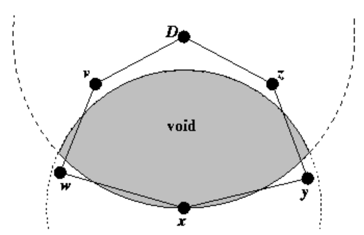
- Nodes learn 1-hop neighborhood nodes' current position from beacon exchange packets
- Current node S forwards packets to its neighbor node A closest to Destination node D



Failure Scenario - Greedy forwarding not always possible!
•No node closer to destination than Current node itself -> Local Maxima
•Situation commonly referred as "Routing Void"

Perimeter Routing

- Apply right-hand-rule to traverse the edges of the void and find a path using the topology's perimeter
- Perimeter Routing uses longer paths to the destination - less efficient and cannot be used alone



Drawbacks of Geographic Routing

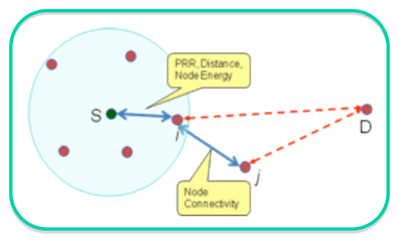
- "Routing Void" encountered during greedy forwarding necessitates the need for a secondary void handling technique.
- Perimeter mode highly energy inefficient.
- Algorithm does not consider any additional network or node parameters vis.-a-vis. link quality between current node and the candidate node, residual energy level of the candidate node or the connectivity information of the candidate node.

Modified Versions of Greedy Forwarding in Literature

- Distance and Node Residual Energy Based
  - Nodes have Limited Battery Resources
  - E_{THR} - Threshold Energy Level maintained to prevent overuse of low energy nodes.
- Distance and Link Quality Based
  - Packet Reception Rate (PRR) used as a measure of link quality between 2 nodes.
  - Metric – PRR * D
- Distance and Node Connectivity Based
  - Connectivity Factor – Number of neighbours in 1-hop neighbourhood of each node
  - Metric – Weighted sum of Distance towards Destination and Node Connectivity Factor
- 2-Hop Neighbor Information Based
  - NIR uses only the second hop neighbour location for routing decision.
  - Choose the node connecting current node and chosen node as the next hop node.

Proposed Routing Scheme

- 2 Hop Information Considered for routing decisions:
  - Hop 1: Normalized Distance From Destination, Link Quality (PRR), Node Residual Energy
  - Hop 2: Node Connectivity Information



Advantages

- Maximize use of modified greedy forwarding scheme by preventing areas close to routing voids using the node connectivity information to predict the location of routing voids
- Energy balancing, maximizing the network lifetime by prevent node failure due to energy drainage
- Higher Throughput, by using links with Higher PRR, thus leading to lower packet drops and retransmissions
- Eliminates need for a secondary routing scheme, supplementing it with "*forward-progress*" and "*reverse-progress*" modes of the routing algorithm.
- Forward packet in a multi-parameter greedy forwarding manner using the proposed routing metric, even if the packet encounters a deadlock situation.

Models and Preliminaries

■Link Quality Model:

- The propagation model utilized here is based on the log-normal shadowing model.

$$\left[\frac{p(d)_{i,j}}{p(d_0)}\right]_{dB} = -10\beta\log\left(\frac{d}{d_0}\right) + X_{dB}$$

- Packet Reception Rate: Represented as a probability of successful transmission as, $0 \le p(d) \le 1$

$$p(d)_{ij} = \left(\frac{D_0}{d_{ij}}\right)^{\gamma}$$

■Node Connectivity Model:

- Nodes close to Void/Network Edge – Low Connectivity
- Low Density – Deadlock situation
- *Forward Progress* : Candidate Nodes closer to Destination as compared to the current node

$$c_i = N_{i,j}^{adv} \qquad N_{i,j}^{adv} \in N_{i,j}$$

■Node Residual Energy Model:

- Captures the residual energy levels of nodes.

$$E_{norm\text{-}j} = \frac{E_{resi\text{-}j}}{E_{max}}$$

- Major factors utilizing a nodes' energy resources are the wireless radio processes of packet reception and transmission

■Node Distance Model:

$$f_j = \begin{cases} 1; \ if\ d_j < d_i \\ -1; \ if\ d_j > d_i \end{cases}$$

- $d_j < d_i$: Forward Progress Mode
- $d_j > d_i$: Reverse Progress Mode

■Modified Beacon Exchange Protocol:

- *HELLO* message packet periodically prepared by picking up required values from the nodes and broadcasting to the neighbours.
- Frame format for the *modified HELLO message* packet:

Node ID	Current Location Information	Residual Node Energy	Node Connectivity Information

Design of Proposed Geographic Routing Metric

- 2-hop neighbor information
- Combines effects of multiple network and node parameters

$$w_{i,j} = \left[\alpha * p(d)_{i,j} + \beta * c_j + \delta * E_{norm-j}\right]$$

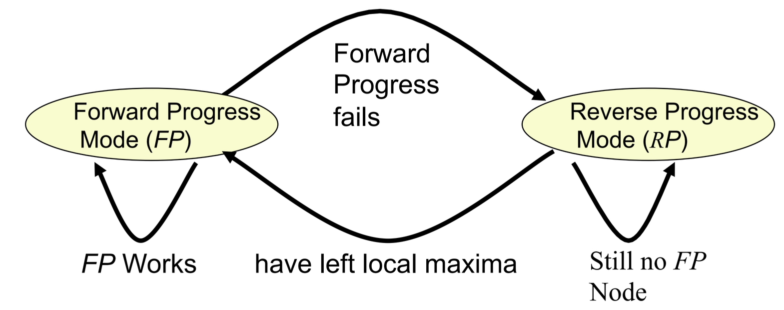
where

$$(\alpha+\beta+\delta=1)$$

Given

$$c_j > 0$$

- Node distance parameter driving the behaviour of the routing metric by separating *forward progress* nodes from candidate nodes that lie behind the current node.
- The routing decision is based on maximum value of $w_{i,j}$ among all the candidate nodes j.
- Select forwarding node with good link quality, high residual energy having more forward progress nodes as compared to the rest of the 1-hop candidate nodes.



2-Hop Neighbour Information Based Energy- Efficient Multi Parameter Geographic Routing Algorithm

Objective: to select the next forwarding node j

Multi Parameter Greedy Forwarding: when node i receives a data packet, it compute $w_{i,j}$'s for all candidate nodes j

a. ***Forward Progress Mode***: Choose node j^* corresponding to the highest value of $w_{i,j}$'s from *forward progress* candidate nodes, represented by the positive values for $w_{i,j}$

b. ***Reverse Progress Mode***: If no forward progress node is available in the candidate set, choose the node j^* corresponding to the highest value of $w_{i,j}$'s from the *reverse progress* candidate nodes, represented by the negative value of $w_{i,j}$

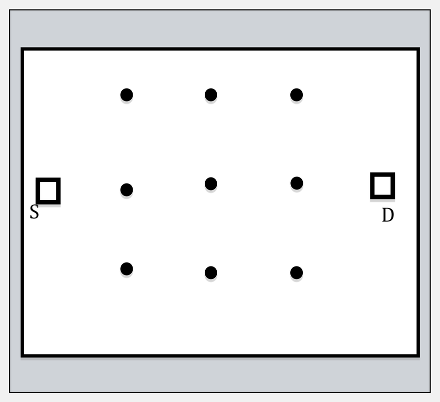
Evaluation Parameters

Packet Delivery Ratio (PDR): Ratio of number of packets successfully delivered to the total number of packets generated at the source node.

Network Lifetime (NL): Time before the first node in the network dies out due to depletion of its limited energy resources.

Simulation Environment and Simulation Results

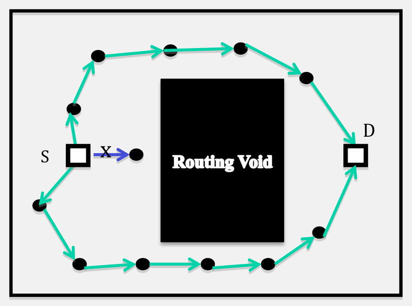
■ Simulation Scenario 1:



- *Primary objective*: Verify the energy balancing behavior of the proposed routing scheme due to the multiple alternate paths traversed during packet forwarding.

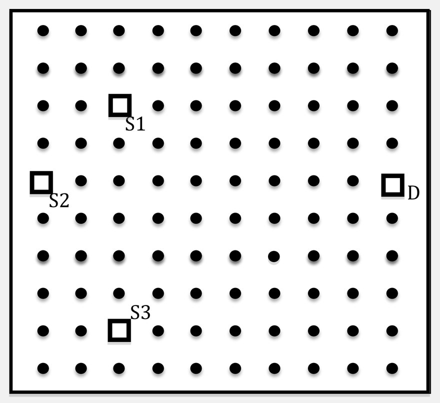
	Modified Geographic Routing	GPSR
Packet Delivery Ratio	113/150	76/150
Network Lifetime (seconds)	185	140

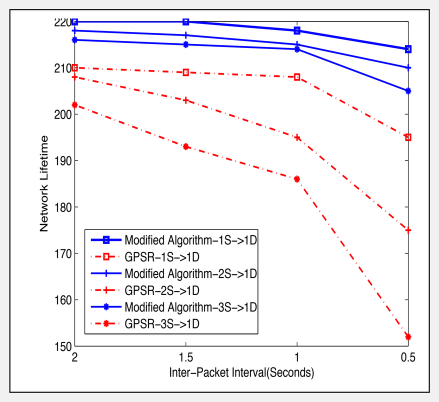
■ Simulation Scenario 2:



- *Motivation*: Verify behavior of the routing algorithms being compared in case of encountering a routing void.
- Proposed Scheme predicts and avoids routing towards Deadlock Node.

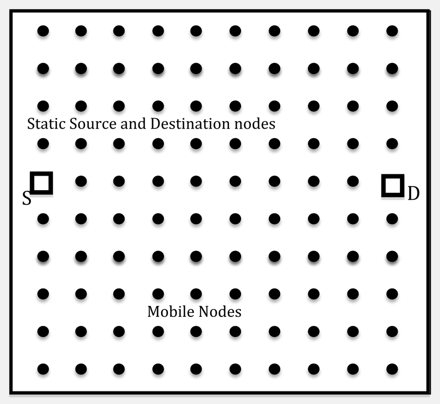
■ Simulation Scenario 3:

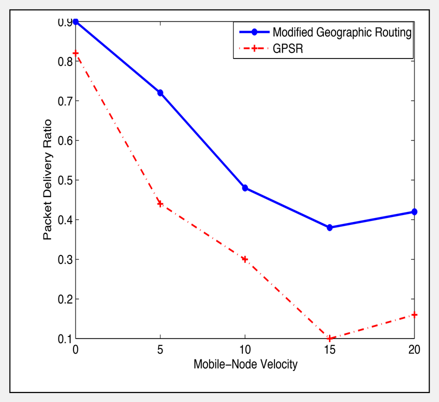




- Improvement due to Node Residual Energy Information.
- Begin with one Source-Destination pair (S1-D). Add additional Sources (S2-D, S3-D) to generate traffic to increase load on network.

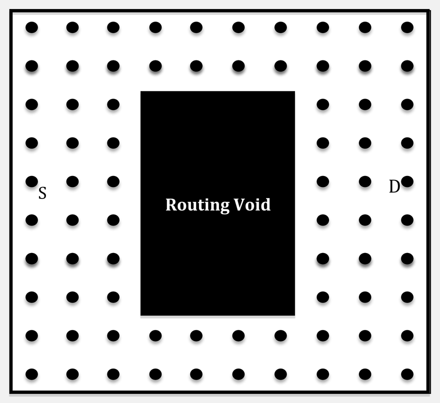
■ Simulation Scenario 4:

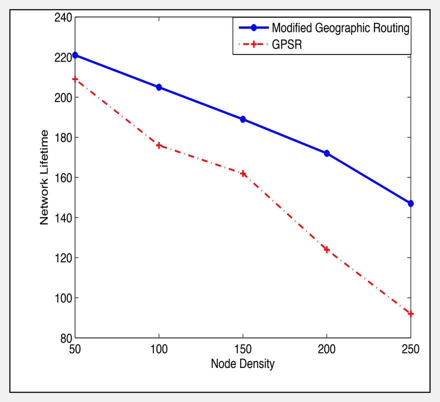




- Improvement due to Link Quality Information.
- Source-Destination Pair static, rest all nodes in the network mobile, movement pattern based on Random Waypoint Model.

■ Simulation Scenario 5:





- Improvement due to Second-Hop Forward Connectivity Information.
- A routing void placed between the Source-Destination Pair.
- Measure the effect of energy balancing of the network.
- GPSR: Always same path around routing void.
- Proposed scheme: Load balancing to increase network lifetime.

Conclusion

- Presents a novel multi-parameter Geographic Routing Algorithm which eliminates the need for a secondary routing scheme, unlike classical Geographic Routing algorithms.
- *FUTURE WORK*: The proposed scheme will be tested and optimized over the wireless sensor network testbed with a combination of medical and environmental sensors.

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