Aligned Virtual Coordinates for Greedy Routing in WSNs

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Outlines

- Motivation of Virtual Coordinates System (VCS)
- Brief introduction to GPSR/GFG (Geographic Routing)
- Anomalies in VCS
- Intuition and Design of Aligned VCS
- Performance evaluation
- Conclusion
Motivation of VCS

• Geographic Routing Efficient for WSNs
  – *Stateless*: no state information (info of sink and path)
  – Localized Interactions (only info of one-hop neighbors)

• GR suffers from *Voids* and Localization Errors

• Virtual Coordinate Systems (based on connectivity info.)
  – Better? Based on partial connectivity info.
    * We show they suffer their own anomalies
    * Quantization Error is a factor
GPSR/GFG: Greedy Forwarding (GF)
GPSR/GFG: GF may fail
Distance Map Show

Distance Map of a physical hole

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Virtual Coordinates For Geometric Routing

- Several nodes are elected to be anchors: one node per dimension;

- Anchors broadcast Virtual Coordinate beacons;

- Each other node forwards beacons, incrementing distance;

- Each node obtains a VC based on received beacon values;

- Distance measured in number of hops: integral value;
Argued VCS (VCap)

- 3 anchors (a 3D VCS) are enough to map the physical coordinates

- VC Zone can be avoided if density is high enough
  
  VC Zone: nodes with the same VC values

- VC Zones are connected with 3 anchors adapted (3D VCS)

- Void (anomaly) ratio is reduced much
Anomalies found in VCS

- 3D VCS is not enough to map
- VC zones may be disconnected in 3D VCS
- Anomaly ratio may be increased by VCS
  - More routing (greedy forwarding) anomalies happen
Anomalies in 3D VCS

Extended & Disconnected VC Zone Problems

Details can be found in previous work
Anomalies in 3D VCS (virtual voids)

Virtual voids even without physical void
4D VCS? or Different Distance measurement?

- 4D VCS was proposed too (LCR)

- Anomalies in 4D VCS were found in LCR; solution requires each data packet records each node along its path during forwarding

- Different distance measurement was prosposed (BVR), Manhattan style distance, indicated as a better solution
Existing solutions do not reduce anomalies

Eclidean Distance in 4D VCS

Manhattan Distance in 4D VCS

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Reducing Anomalies– Greedy Forwarding Better

In terms of Average Path Stretch

<table>
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<th>Density Neighbors #</th>
<th>Optimal</th>
<th>GF</th>
<th>Perimeter Routing</th>
<th>CR</th>
<th>BVR BT</th>
<th>LCR BT</th>
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<td>4D VCS</td>
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</table>

Observation: if we can increase the ratio of greedy forwarding, we may improve the routing performance: either path stretch or overhead

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Why Anomalies in VCS?

- Virtual Coordinate values are **integral**: quantization error or noise increases requiring more precise values for VCs

- No discrimination among nodes in range: forwarding dilemma requiring in range discrimination

- Mapping from a continuous space to a **discrete** space: less forwarding candidates requiring **continuous** space
Node A and B are different as forwarding nodes, since with different regions of neighbors in their range.
Aligned VCS (AVCS)

- **AVC of a given node** is computed as a function of its VC and neighbors VC.

- Simplest value: *average* of the neighbors’ integral virtual coordinate values.

- AVC coordinates with depth $d$ are decided by its neighbors aligned virtual coordinates with depth $d - 1$.

- Original integral virtual coordinates are AVC with depth 0.
AVCS (cont’d)

Forwarding Voids in 4D VCS

Aligned VCS without forwarding voids
Simulation

- Metrics:
  - **Greedy Ratio**: how many paths do not face any anomalies
  - **Path Stretch**: the average length of all paths (both GF and CR) compared to optimal solution (SP)

- Simulator:
  - **NS-2**: for network with less than 400 nodes
  - **Customer**: for network with 1600 or 2500 nodes

- Based more than 30 networks used for each scenarios
AVCS Performance: Greedy Forwarding Ratio

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AVCS Performance: Greedy Forwarding Ratio over BVR

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AVCS Performance: Path Stretch

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AVCS Performance: Path Stretch over BVR

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AVCS Performance: Depth

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AVCS Performance: GF ratio with random deployment

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AVCS Performance: Path stretch with random deployment

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Conclusions

- Greedy Forwarding performs much better than complementary routing phase;

- Virtual Coordinates System with simple integral values create more anomalies than Geometric Routing;

- Aligned VCS help reduce anomalies, enhancing performance;

- Geometric Routing in VCS (AVCS) can provide equivalent, or even better performance, than geographic routing;

- Further, stateless routing can approach that of “stateful” routing protocols, such as shortest path routing.
Thank You!

Code is available on my website
http://www.cs.binghamton.edu/~kliu

Questions?
Back up : Multiple Physical voids

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