Component Based Localization in Sparse Wireless Ad Hoc and Sensor Networks

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Roadmap

- Motivation
- Problem formulation
- Node base algorithms
- Component bAsed Localization aLgorithm (CALL)
- Experimental evaluations
- Future work
Motivation

- Location information is critical context
  - WSN: Fire alarm!
  - Manager: Where? Where?
  - WSN: I don’t know! I have no location knowledge!
- Location information facilitates many network designs
  - Geographic routing, coverage, boundary/ hole detection, …
Sparseness in Localization

- Localization depends on inter-node distances
  - Naïve approaches are not feasible
- Information insufficiency influences localization much
  - The distance-measurement ranges are typically much less than that of communication range for many ranging systems
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Basic Assumptions

- Localization in a 2-D plane
- Accurate ranging
- General graph
Problem Formulation

- **Given**
  - Anchor positions
  - A set of inter-node distances

- **Objective**
  - Find a mapping of node-positions
  - Fulfills all the anchor positions and inter-node distances constraints
  - The result set is finite
  - The real position of each node must be a candidate in the result set
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Node Based Algorithms

- Localizing nodes by a series of trilaterations or bilaterations
Node Based Algorithms

- When network becomes sparse …
- None of them can be localized!
Node Based Algorithms

- Require anchor proximity
  - Nodes must find enough anchors in direct neighbors to start the localization procedure

- Restrict nodes to be localized in order
  - Halt when no single node can perform trilateration or bilateration, no matter whether there are localizable nodes
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Component Based Localization

- Take the five nodes as a whole
- They are all localizable nodes!
The Concept of Component

- **A component** is a group of vertices that have finite realization possibilities
  - A node can join only one component
  - Any component pair shares no common nodes
- A component is **globally rigid** if and only if there is a unique realization in a plane
- Besides each single node, components are also basic unit for localization
Overview

Component generation

Component realization

Component mergence

Terminate

localizable?

merged?
Component Generation

- **Goal**
  - Partition the network into components and isolated nodes
  - Generate local coordinate system to convert distance information into virtue coordinates

- **Method**
  - A component is formed by a triangle initially
  - Other nodes can join the component by trilateration

- **Note that**
  - All generated components are globally rigid
  - We do not differentiate anchor node and general node in this step
Component Mergence and Realization

- Component mergence: integrate both components and their anchor information
- Component realization: map the virtue coordinates to the physical ones
- For we have generated local coordinate system, we can do these two operations by coordinate system convention
## CALL vs. BCALL

<table>
<thead>
<tr>
<th></th>
<th>CALL</th>
<th>BCALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result</td>
<td>Finite localization</td>
<td>Unique localization</td>
</tr>
<tr>
<td>Proportion of nodes localized</td>
<td>High (super set of BCALL)</td>
<td>Low</td>
</tr>
<tr>
<td>Worst case complexity</td>
<td>Exponential</td>
<td>Polynomial</td>
</tr>
<tr>
<td>Analogue</td>
<td>Bilateration</td>
<td>Trilateration</td>
</tr>
</tbody>
</table>
# Rules for Components Mergence

<table>
<thead>
<tr>
<th>Edges/Associated Nodes</th>
<th>Finite (CALL)</th>
<th>Unique (BCALL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated node</td>
<td>2/1</td>
<td>3/1</td>
</tr>
<tr>
<td>Component</td>
<td>3/2</td>
<td>4/3</td>
</tr>
</tbody>
</table>
Example of Finite Mergence
## Anchor Requirement

<table>
<thead>
<tr>
<th>Finite (CALL)</th>
<th>Unique (BCALL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchors</td>
<td>Anchors</td>
</tr>
<tr>
<td>Edges</td>
<td>Edges</td>
</tr>
<tr>
<td>--</td>
<td>3</td>
</tr>
<tr>
<td>--</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>
For CALL

- Nodes keep all their possible locations in their potential position sets.
- After each mergence or realization, nodes will prune the incompatible items in their potential position sets.
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Future Work

- Investigating theoretical bound of localizability using polynomial spatial-temporal cost
- Extending CALL to handle ranging errors
- Extending CALL to 3-D
Thank You!