



# Component Based Localization in Sparse Wireless Ad Hoc and Sensor Networks

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# Roadmap

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



# Motivation

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- 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

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- 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

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



# Problem Formulation

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- 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



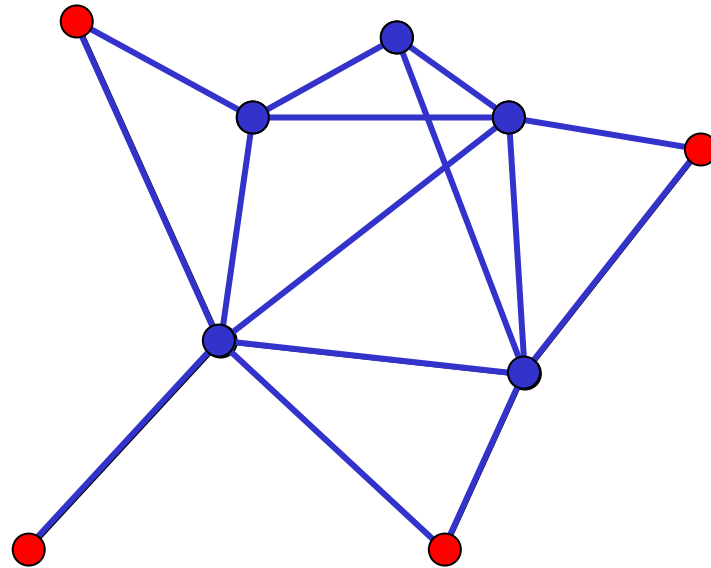
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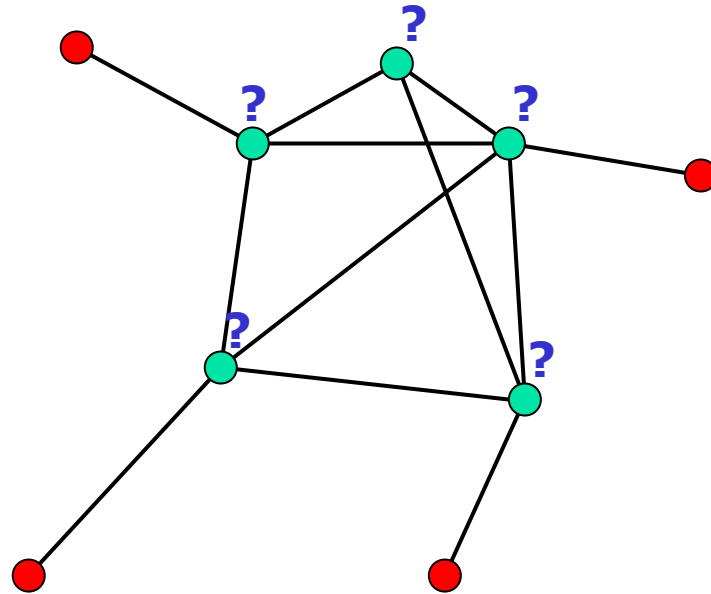
# Node Based Algorithms

- 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

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- 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



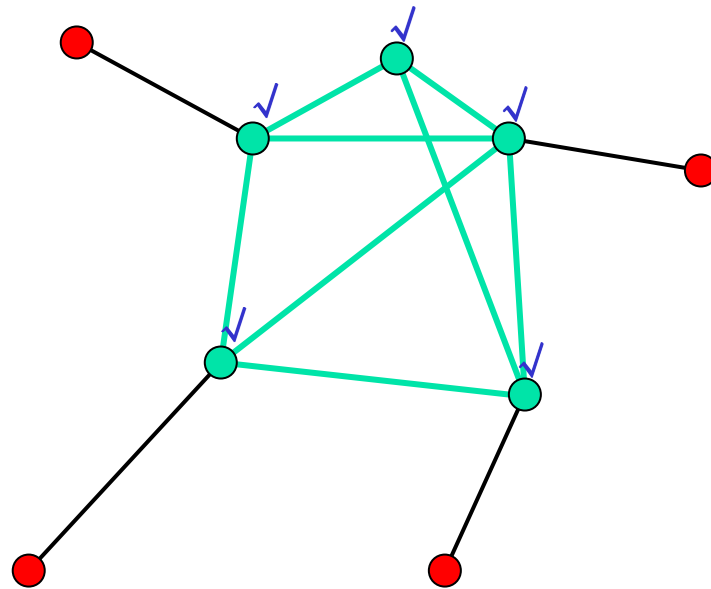
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# Component Based Localization

- Take the five nodes as a whole
- They are all localizable nodes!



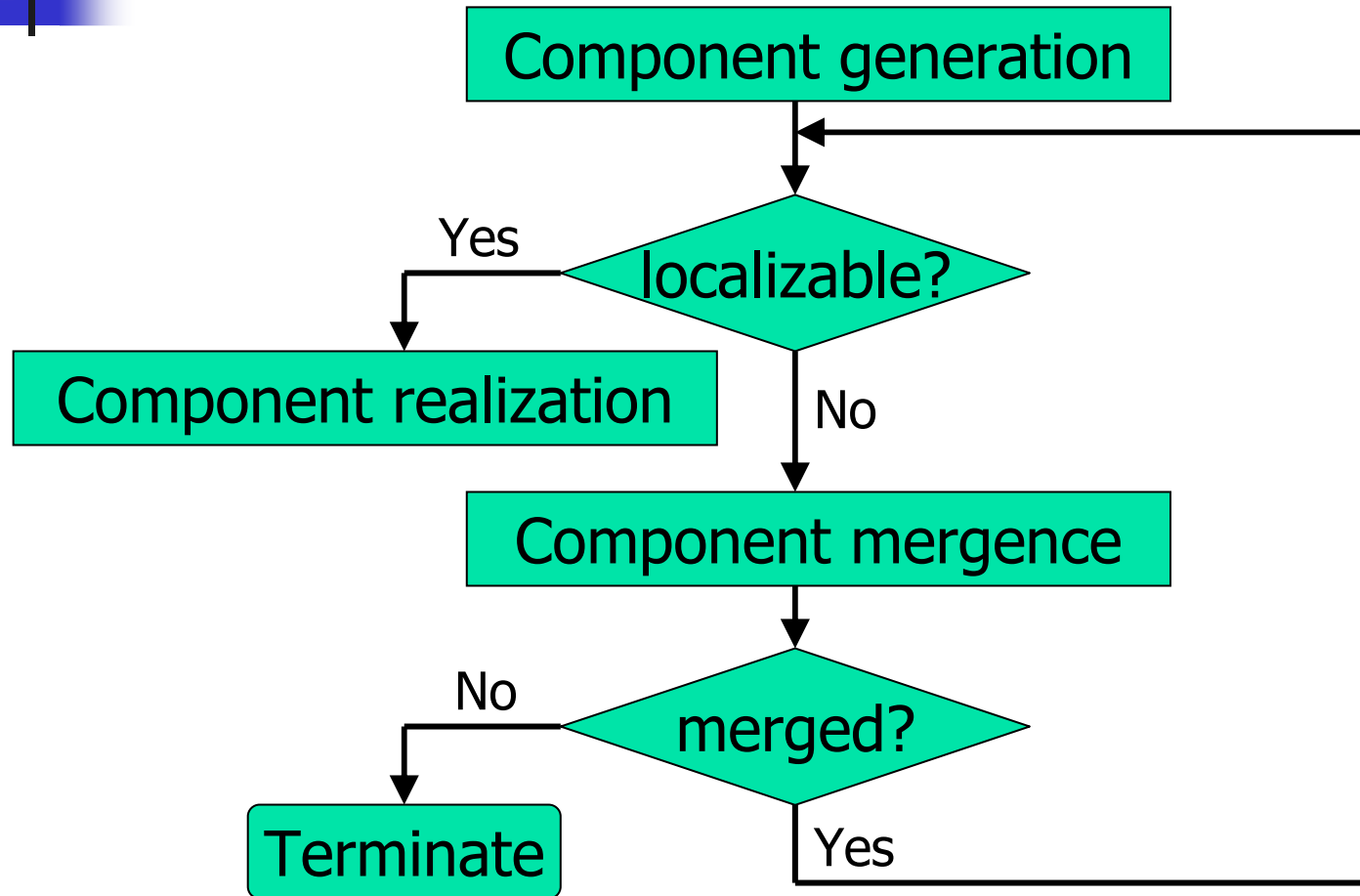


# The Concept of Component

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- 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

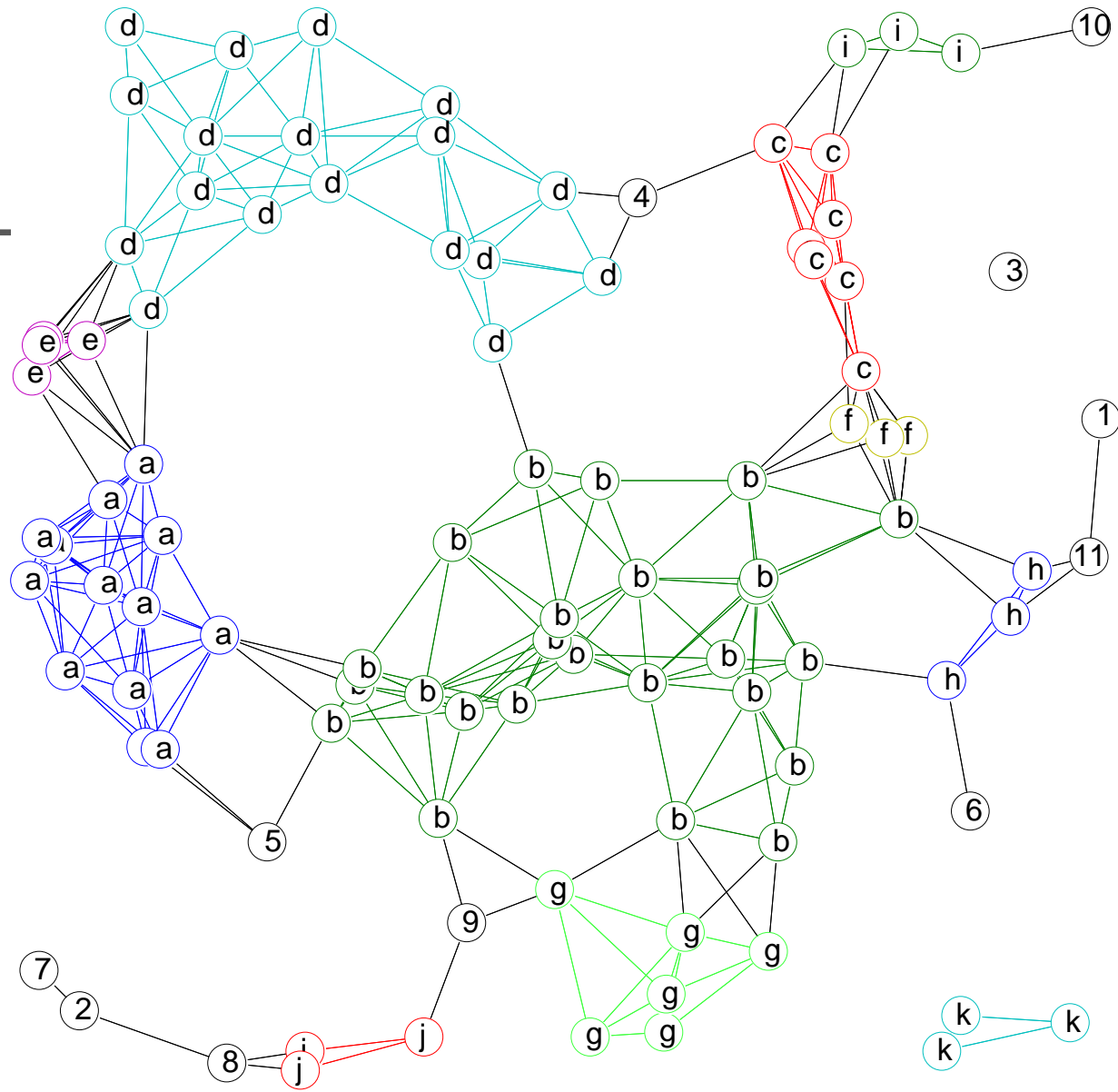
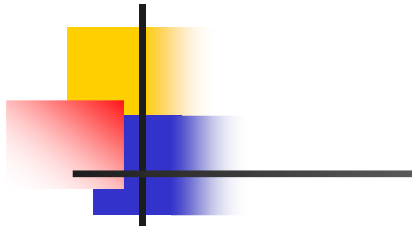




# Component Generation

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- 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

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- 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

|                               | CALL                      | BCALL               |
|-------------------------------|---------------------------|---------------------|
| Result                        | Finite localization       | Unique localization |
| Proportion of nodes localized | High (super set of BCALL) | Low                 |
| Worst case complexity         | Exponential               | Polynomial          |
| Analogue                      | Bilateration              | Trilateration       |

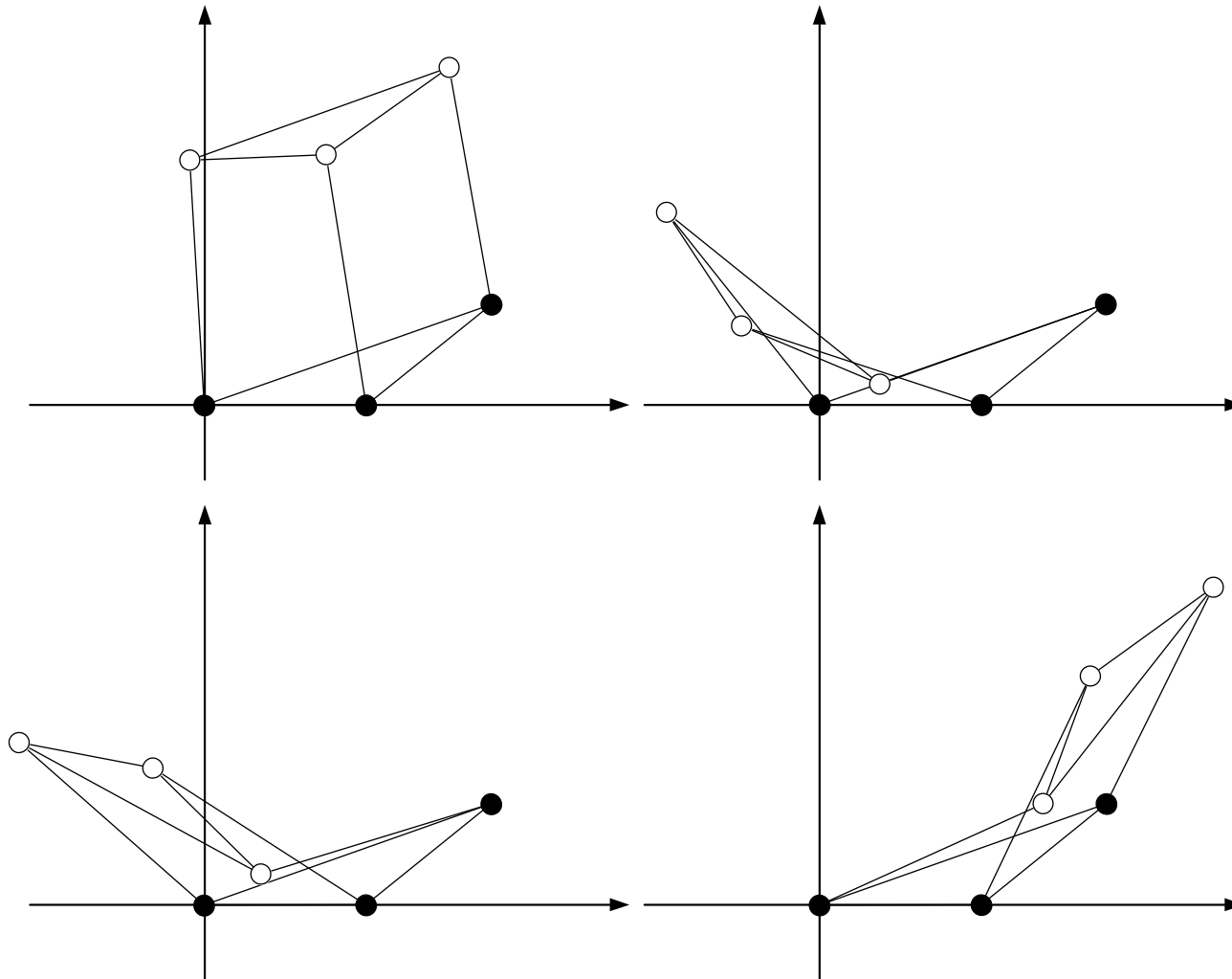


# Rules for Components Mergence

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| Edges/Associated Nodes | Finite (CALL) | Unique (BCALL) |
|------------------------|---------------|----------------|
| Isolated node          | 2/1           | 3/1            |
| Component              | 3/2           | 4/3            |

# Example of Finite Mergence





# Anchor Requirement

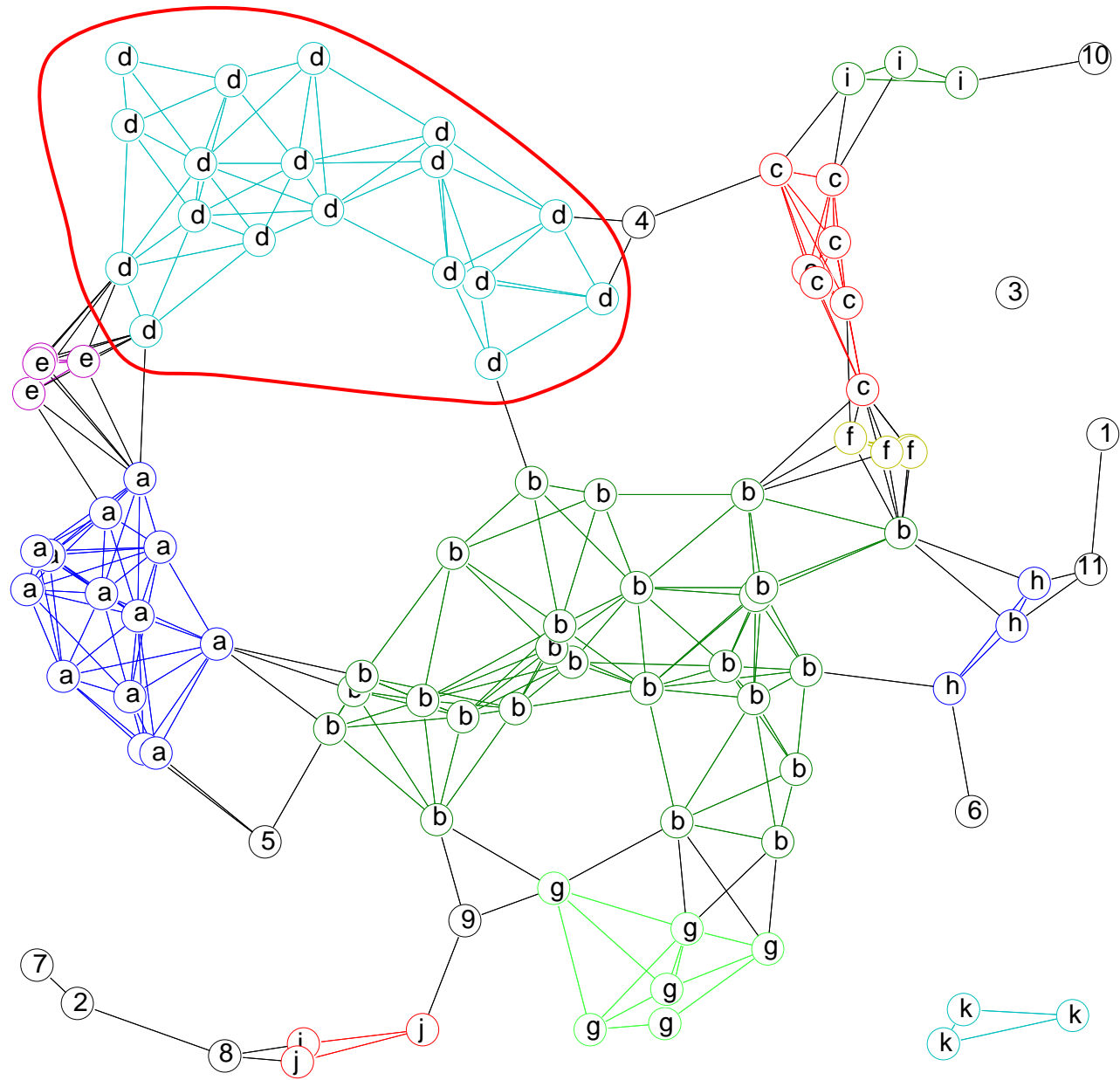
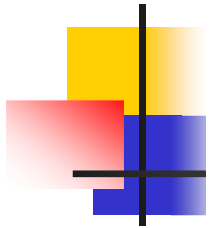
| Finite (CALL) |       | Unique (BCALL) |       |
|---------------|-------|----------------|-------|
| Anchors       | Edges | Anchors        | Edges |
| --            | --    | 3              | 0     |
| 2             | 0     | 2              | 1     |
| 1             | 1     | 1              | 2     |
| 0             | 3     | 0              | 4     |

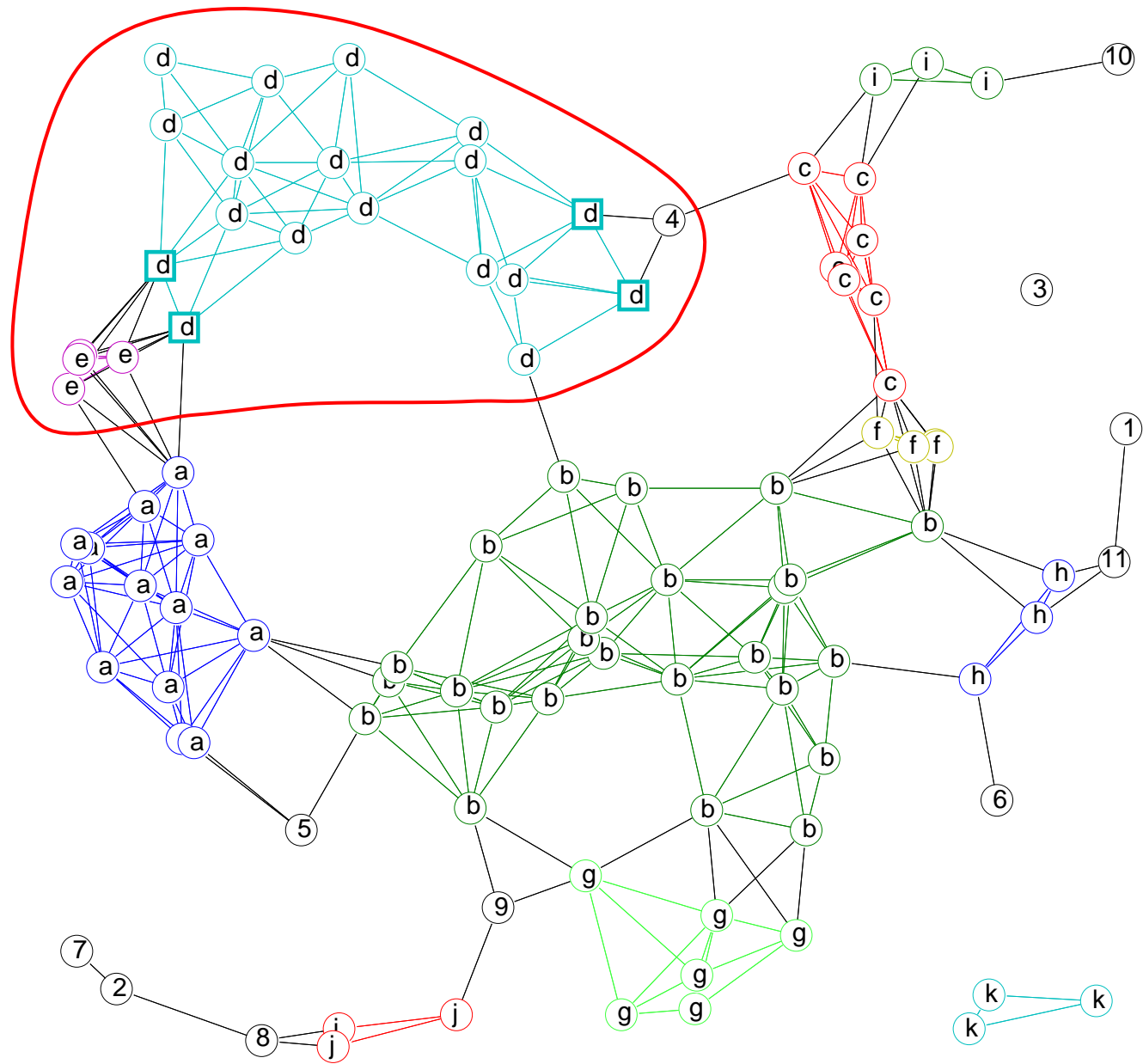
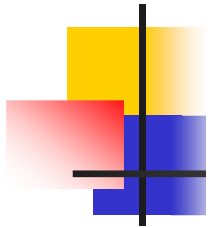


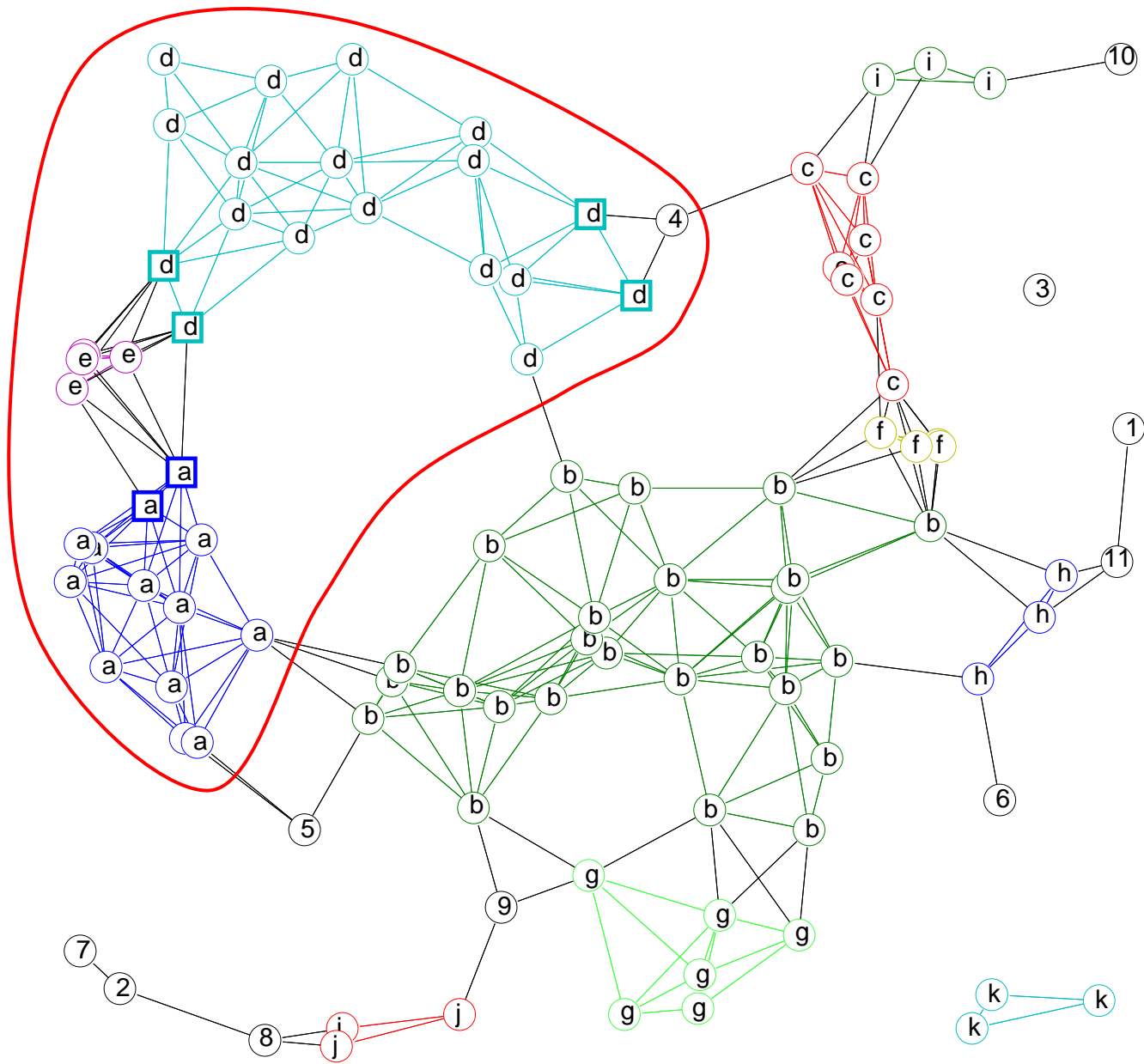
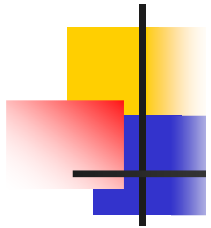
## For CALL

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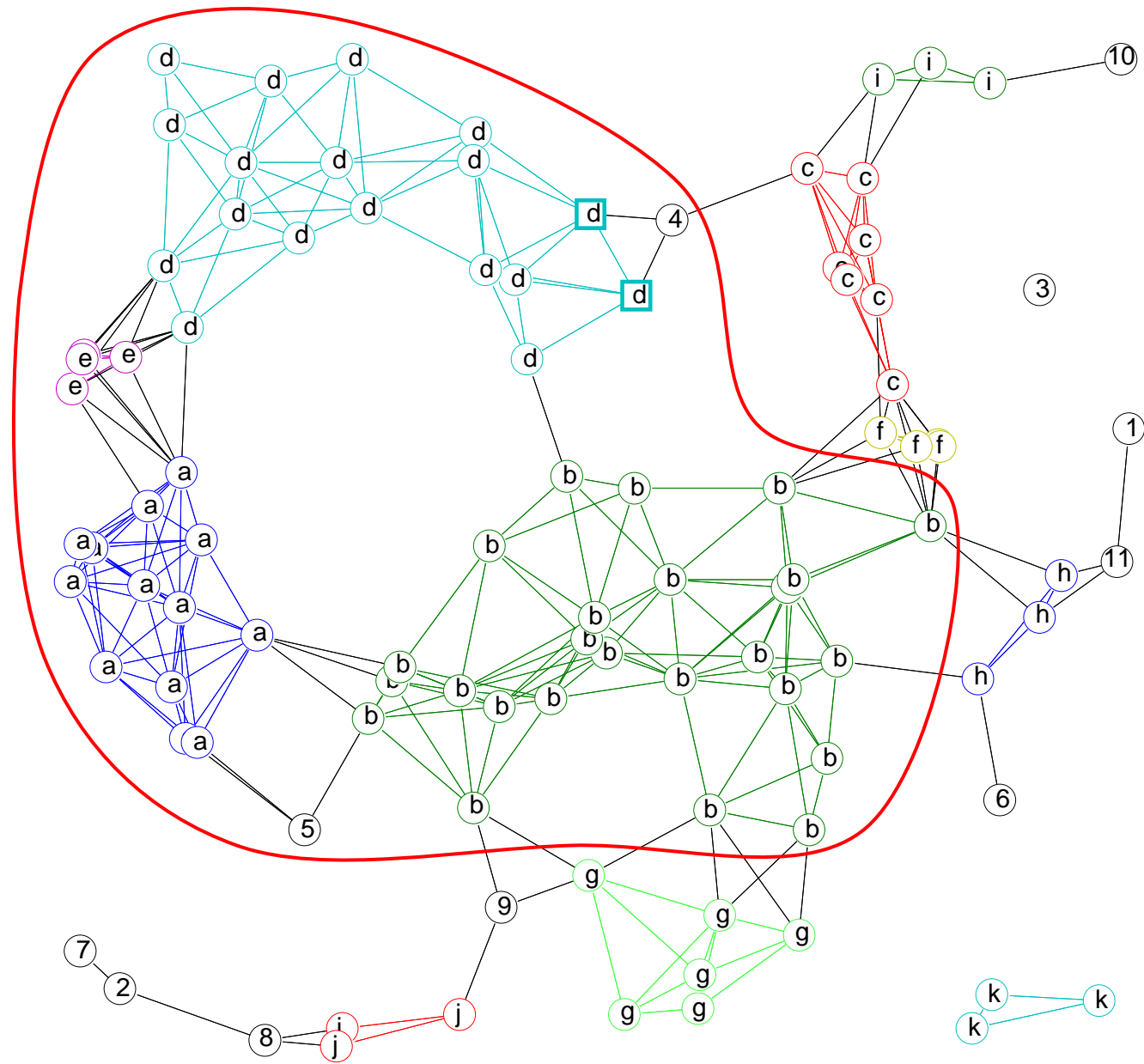
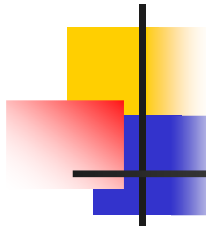
- Nodes keep all their possible locations in their potential position sets
- After each mergence or realization, nodes will prune the incompatible items in their potential position sets

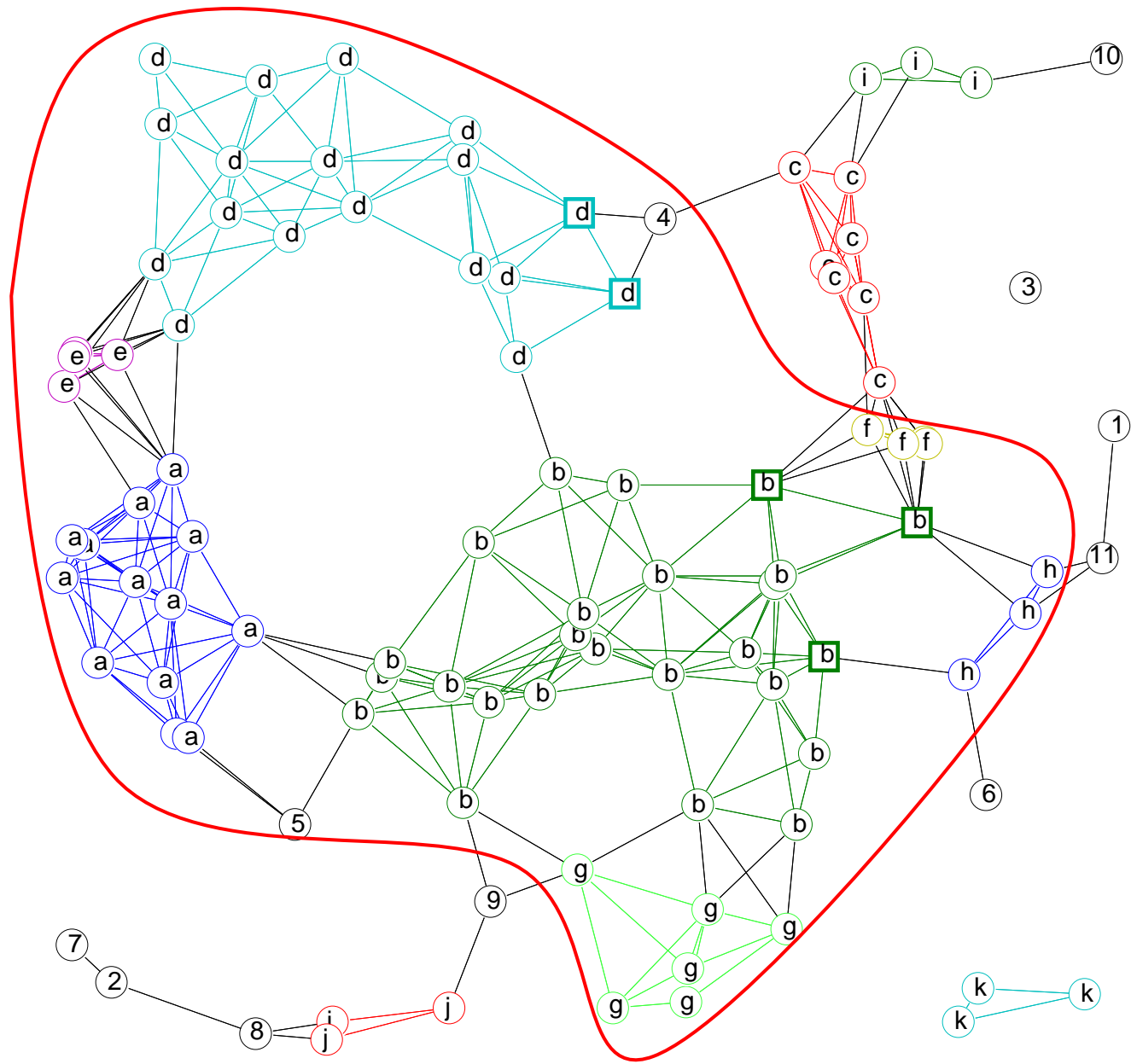
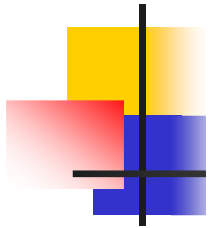


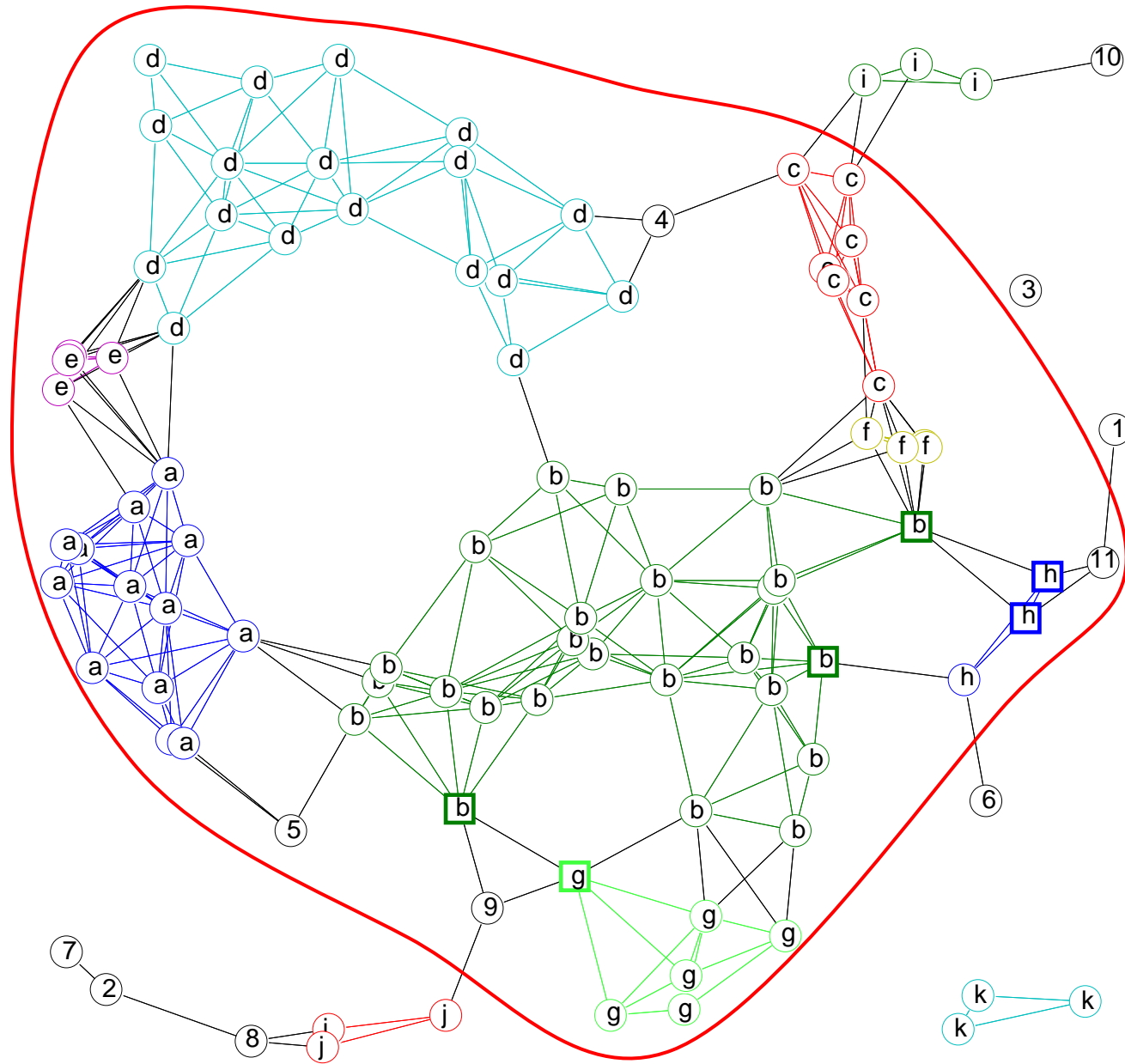
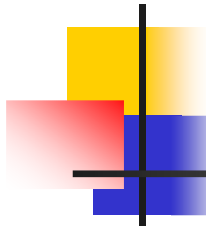


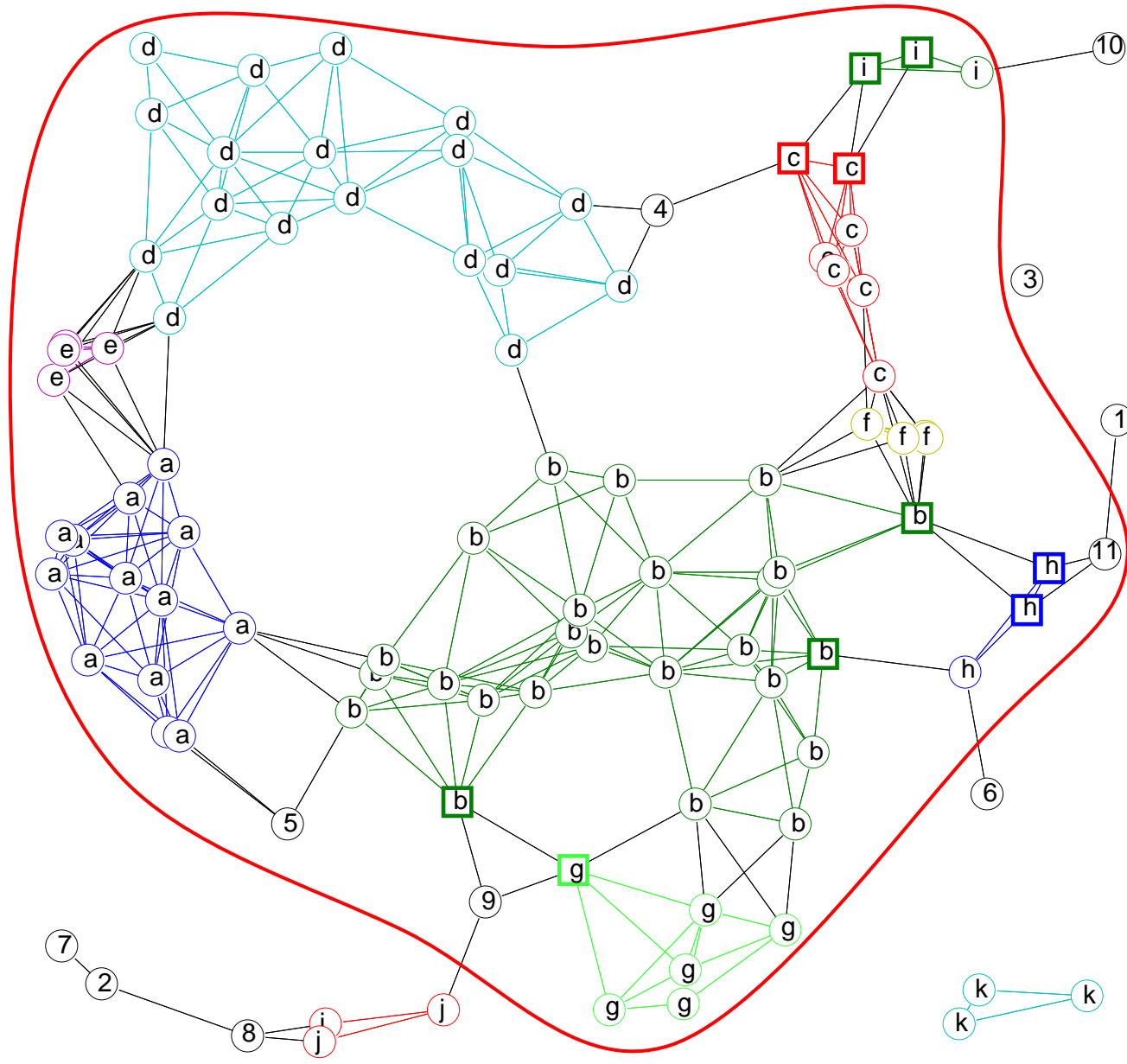
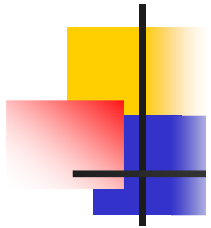














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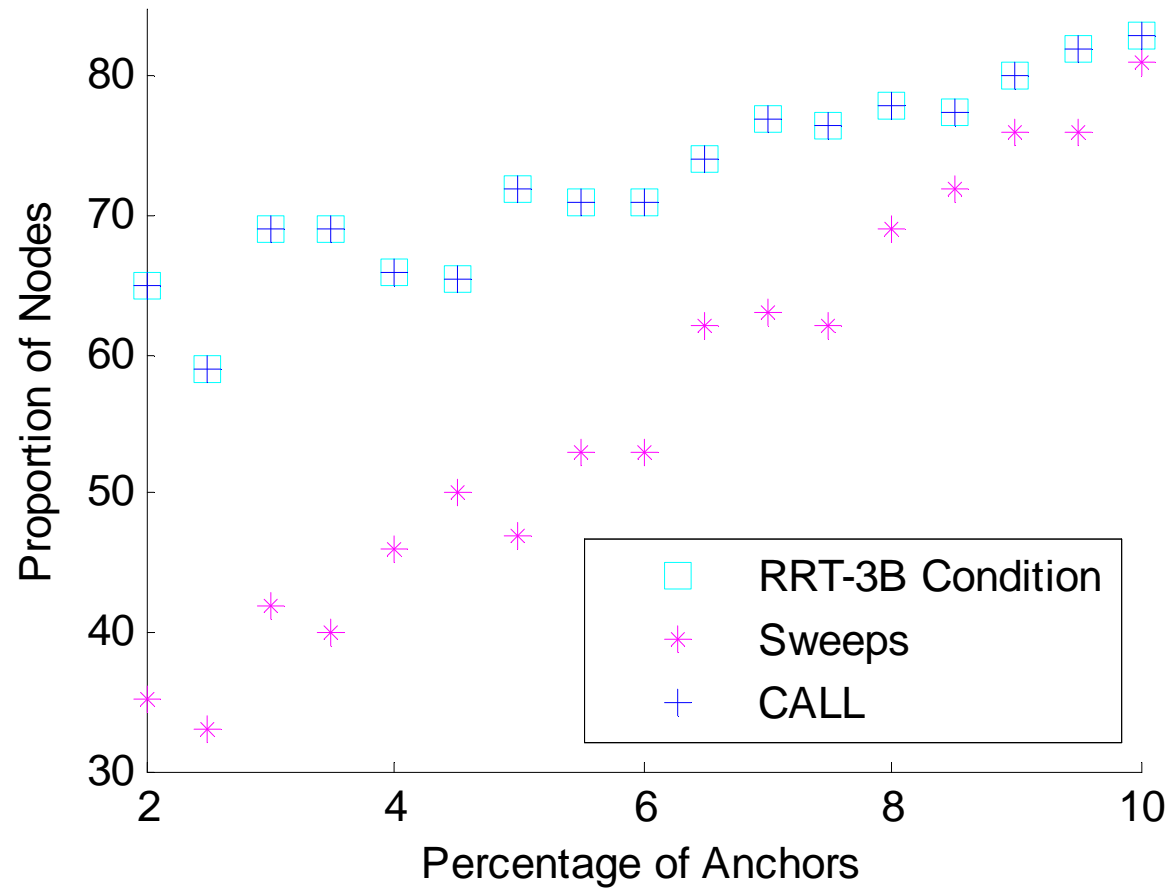
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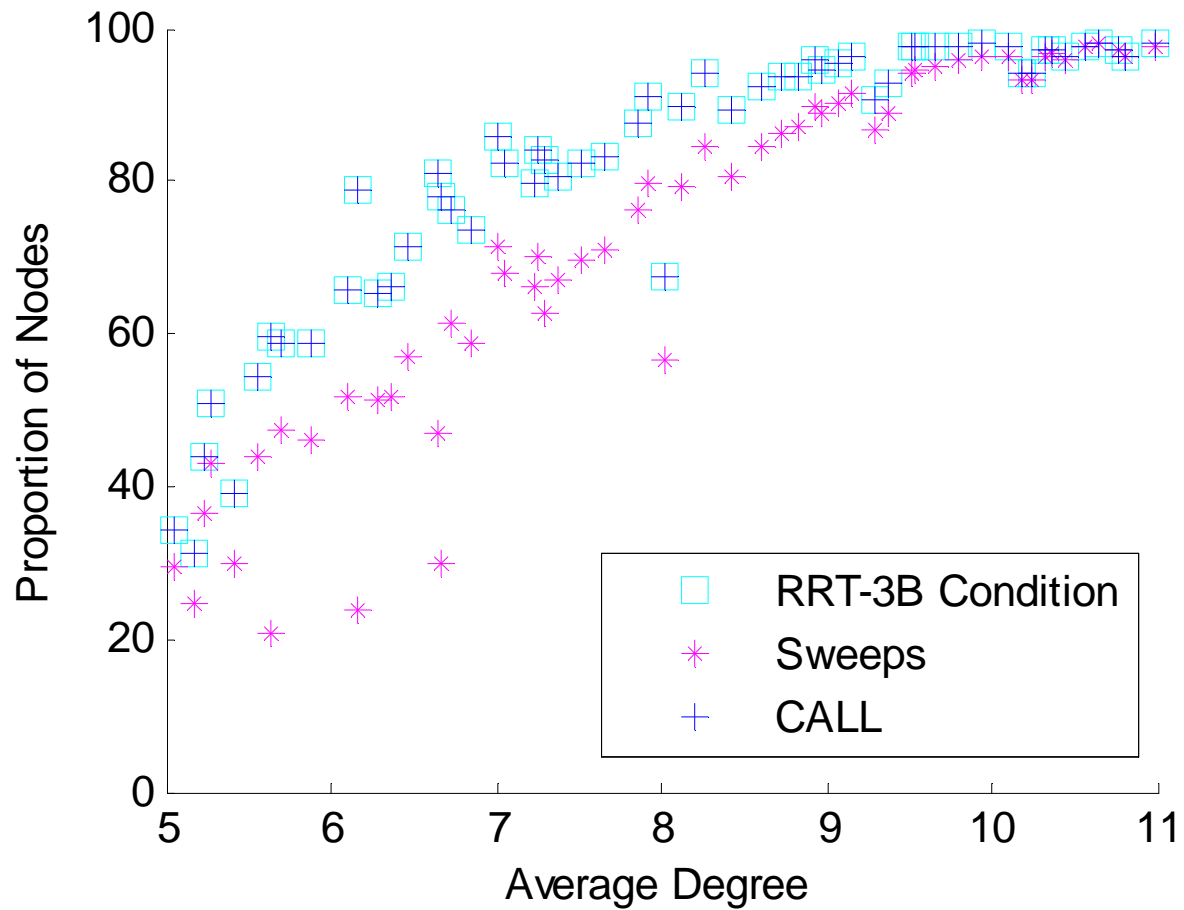


# Nodes-Anchor

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# Nodes-Degree





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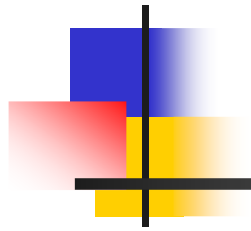
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# Future Work

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



Thank You!

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