MobileLoc: Mobile Localization System for Exploration

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Outline

- Motivation & Problem
- Our Approach and Design
- Implementation & Simulation
- Related Work
- Conclusion

Motivation

- Scenario 1:
  - On Washington mudslide area, a rescue team is looking for survivors and victims in the mountain area.

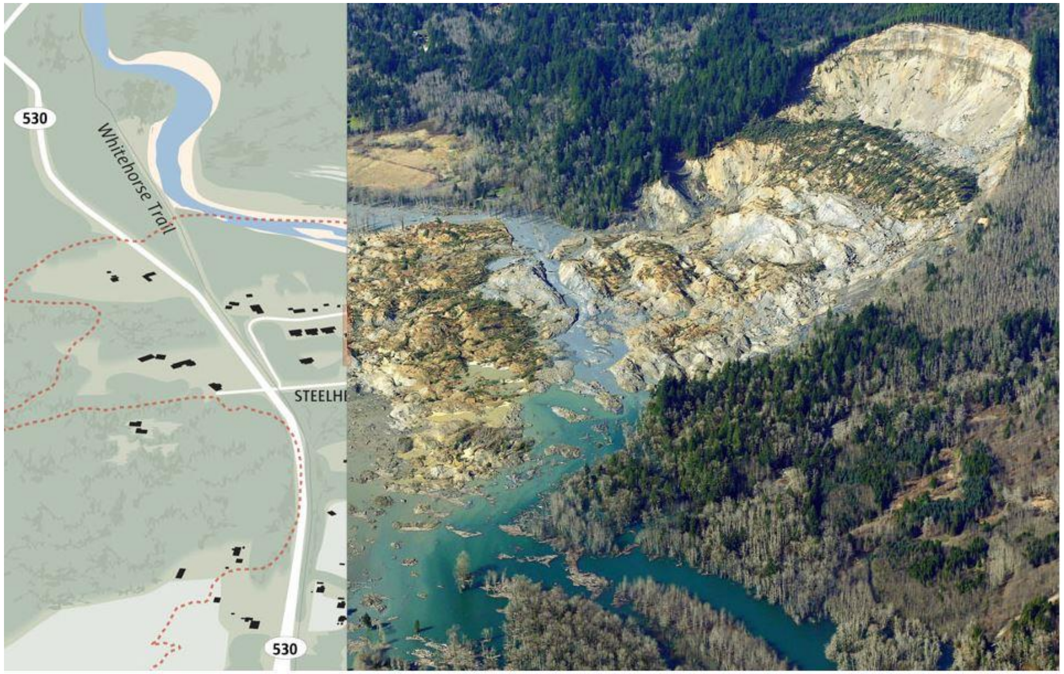


PHOTO BY TED S. WARREN /THE ASSOCIATED PRESS; GRAPHIC BY THE SEATTLE TIMES

Motivation

- Scenario 2:
  - In a forest, an exploration team is in adventure.

Note: all photos adopted in this section are from www.google.com

Motivation

- Other scenarios:
  - On a battlefield, soldiers are searching attacking targets.
  - Mountain areas, a team of travelers in exploration keep contacted without loss.
  - Underground or closet space exploration
- Commons:
  - GPS not applicable or in large error
  - High risk of node losing connections and locations in the mobile network
  - Efficiency of searching an area

Motivation

How about a searching network?

Motivation

Motivation

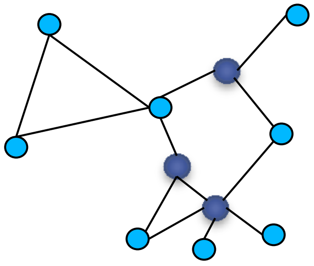
- Requirements:
  - Mobile network
  - Pair communication
  - Network localization (2D plane)
    - Distance measurement
    - Triangulation
- MANET with dynamic localization is the answer!

Network Model

- A network of *n* nodes.
  - Each node has a contact range *d*. When two nodes are within each other's range, a contact happens, denoted as an edge e.
  - Denote as $G\_t(V, E)$, *V* is the set of nodes. *E* is the edge set at time *t*.

Node type

- Two types of nodes
  - Leader:
    - Accurate location as anchor nodes.
    - Least constraint on moving strategy
      - Constraint: network localizability
    - Searching goal maximization
      - Where should the network go?



  - Follower:
    - Inaccurate one-hop or multi-hop localization through triangulation from anchor nodes.
      - Accuracy may decrease as the increment of hop numbers
    - More constraint on moving strategy
      - Constraint: node localizability (subtree localizability), maintain localizability v.s. expand searching area?
    - Searching goal maximization
      - Where should I go?

Distance measurement

- Short radio access
  - In reality, WiFi or Bluetooth.
  - In simulation, a circle area with radius d.
- Distance measurement accuracy simulation:
  - Error range $r < d$
  - Distance in simulation will be $d+r$ or $d-r$.

Localization in the network

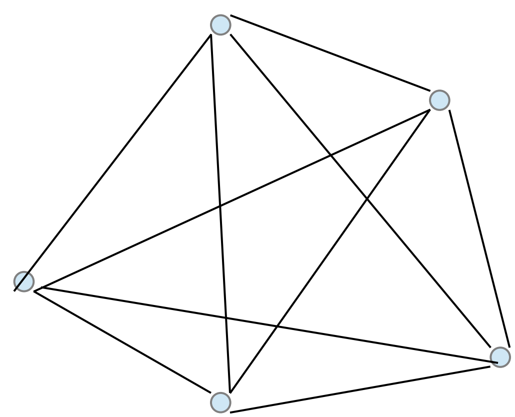
- Basic concept:
  - Location:
    - Position of node ((x, y) in 2D plane)
  - Localization:
    - a process to Determine the location of objects
  - Localizability: a property of node/network
    - Being localizable, if the unique location of a node/network can be preserved.

Localizability

- Localization Theories
  - Graph Rigidity Theory
  - Network Localizability
  - Node Localizability

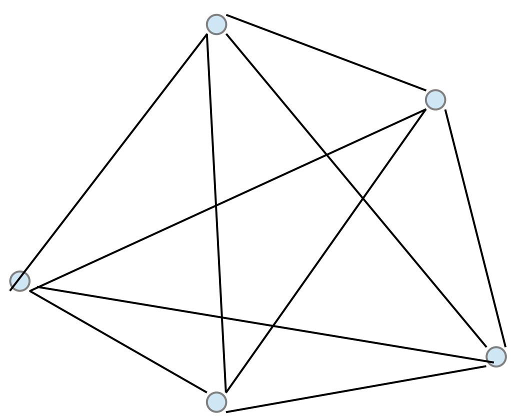
Localizability

- Graph Rigidity [1]
  - A graph is globally rigid if it is uniquely realizable.

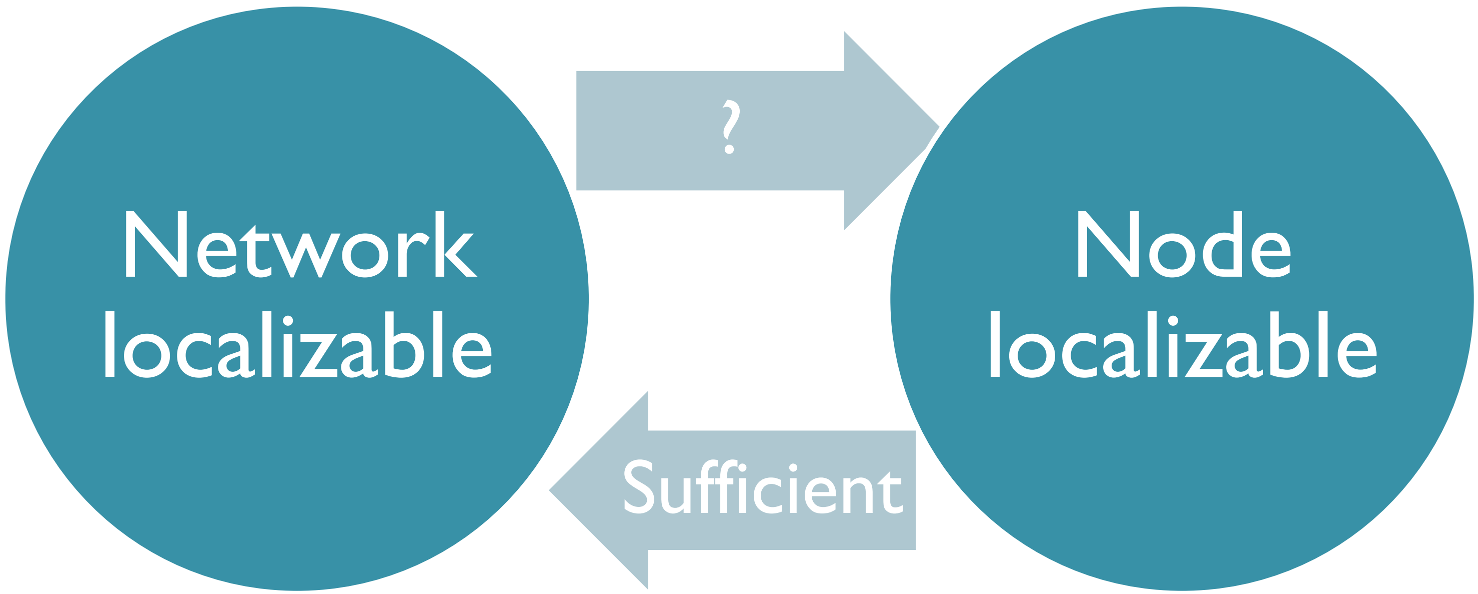


Localizability

- Network Localizability [2]
  - Sufficient and necessary condition:
    - Redundantly Rigid & 3-connected (RR-3B)

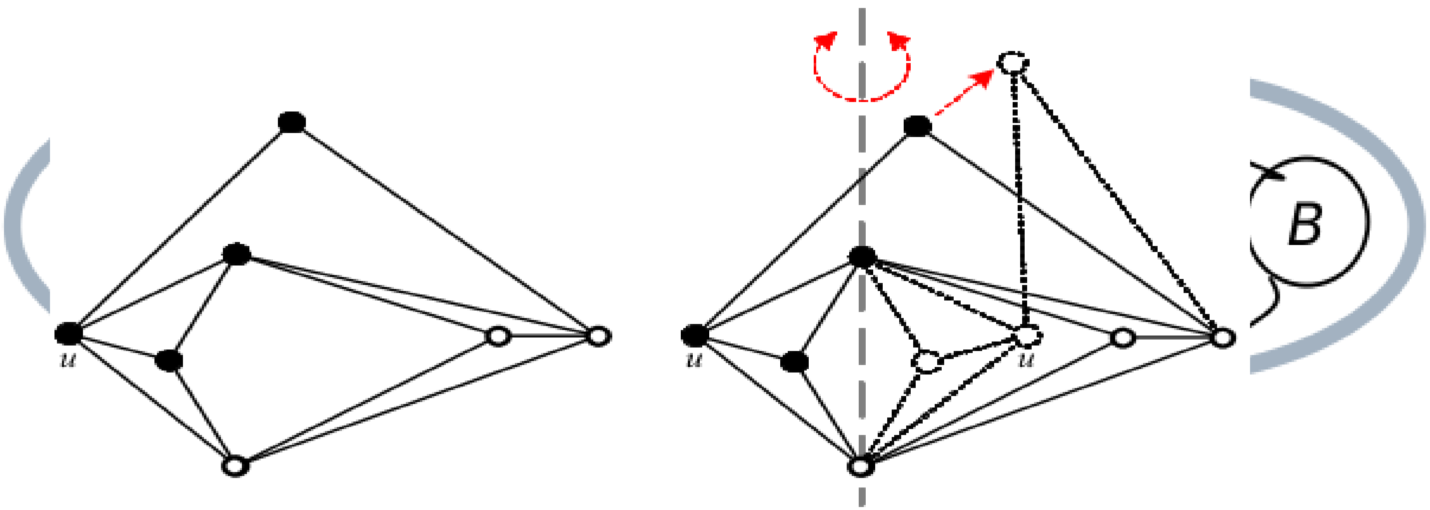


Network Localizability vs Node Localizability



Localizability

- Node Localization [3]
  - Sufficient and necessary condition (RR3P)
    - Redundant Rigidity
    - 3 disjoint paths to beacons
    - 3 disjoint paths in RR component

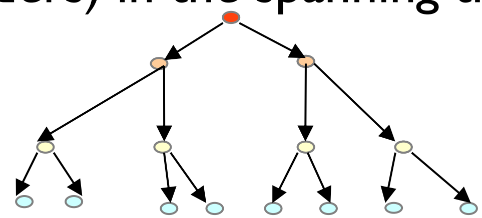


Design Question

- Who is responsible for the network localizability?
- Who calculates the node localization?
- One hop or multi-hop localization
- Three system design
  - Leader Aggregation
  - Follower Autonomy
  - Leader Backbone

Sink Aggregation

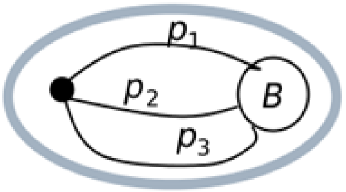
- Aggregation for global topology view
  - Every node reports distance with others to upper layer until the sink (one of the leaders) in the spanning tree structure



- Leader calculate the node location and disseminate location information.
- Limitation:
  - Suffer highly dynamic link
  - Outdated location information due to delay
  - Accuracy highly depends on the depth of the tree structure
  - High energy cost
  - Sink selection and Aggregation strategy needed!

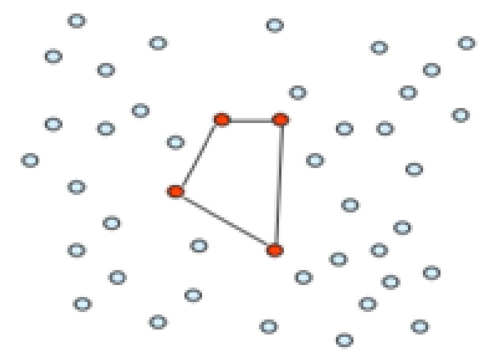
Follower autonomy

- Request and answer:
  - Follower send location request message to neighbors and neighbors relay messages until reach Leader and leader response with the request path to the requesting follower.
- Node gets local topology view and calculate its location by itself
- Limitation:
  - Still suffer the dynamic link
  - May fail to the RR or 3-disjoint paths



Leader backbone

- Leader stay close to each other
  - Provide one hop triangulation to nearby followers and further locate network layer by layer
- Follower calculates
- Pros
  - Easy to implement
  - Easy to locate nodes
- Limitation
  - Leaders distribution are limited in the "center" and network size would be smaller



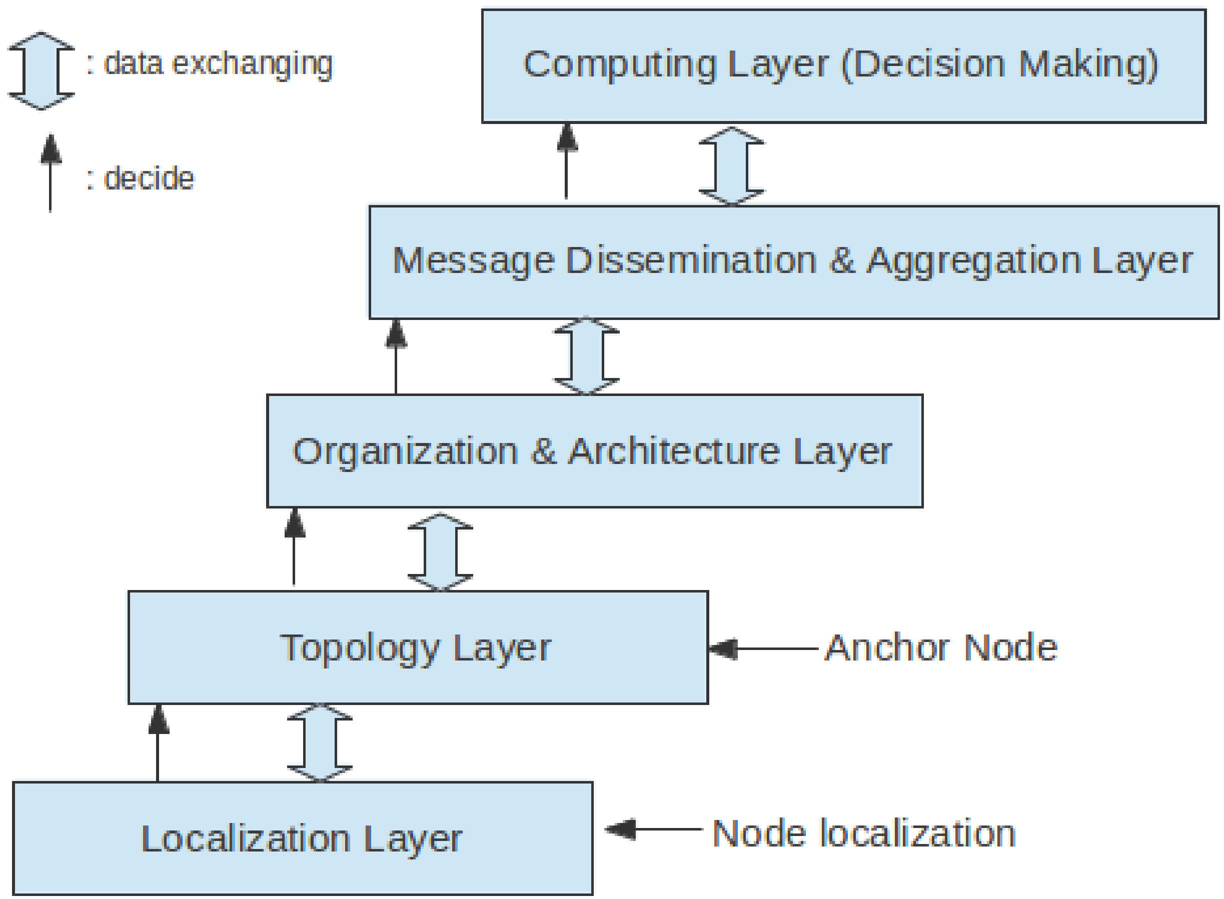
Levels of Localization

- Highest level
  - Rigidity. Redundant links >= 4
- Medium level
  - Links = 3
- Lowest level
  - Links = 2
- Edge of prone loss
  - Links = 1

Objective

- Find maximum area
  - Give up parts of rigidity
  - But the connections of each node must be at least two to ensure the lowest level of localization
- Keep the minimum loss?
  - Keep the highest level of localization

System architecture



Evaluation Design

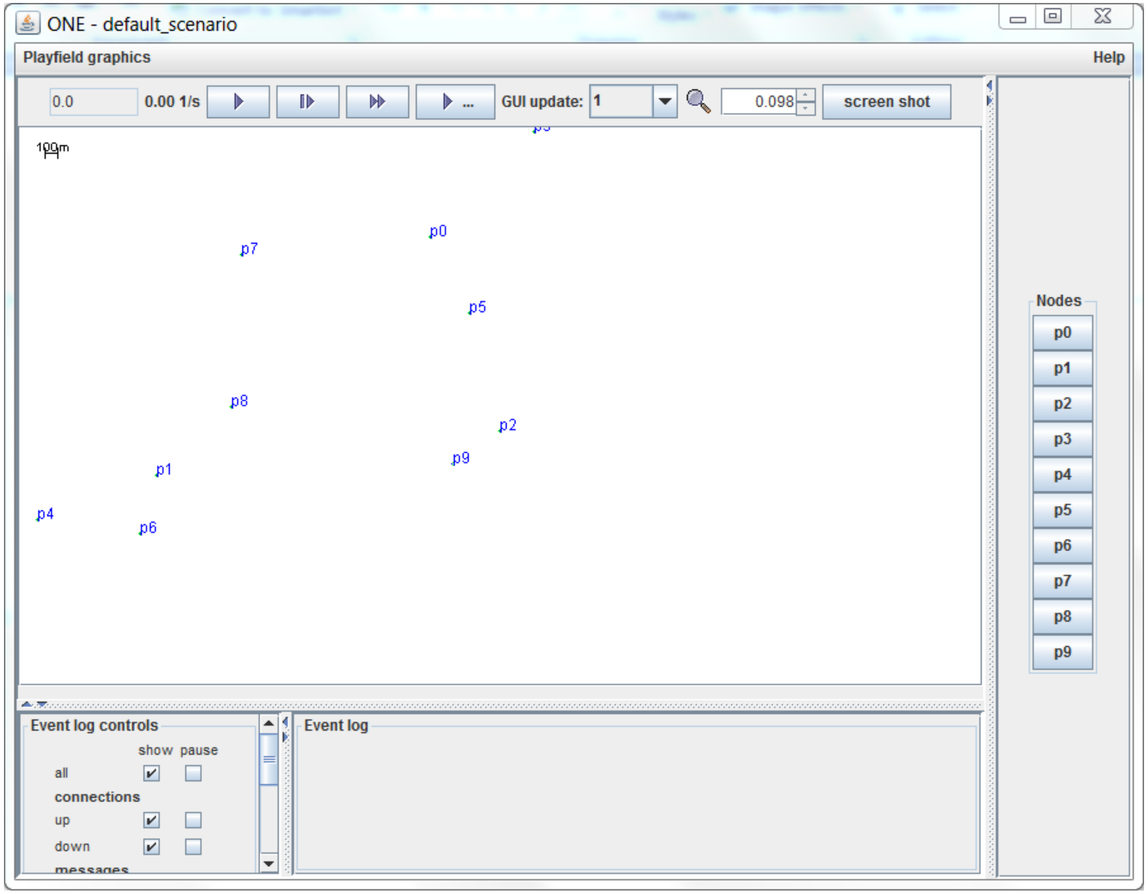
- Three scenarios
  - Rectangle area, moving randomly.
    - Goal: maximize searching area/second
  - Rectangle area with search points.
    - Goal: test search efficiency
  - Localization error rate:
    - Each hop incurs an error range r.
    - Multi-hop may increase errors.
    - Analyze the relationship of error rate and the ratio L/N. L is the leader set and N is the node set.

Simulation &Application

- Simulation based on ONE simulator
  - Implement design 3 Leader-backbone in semester
- Practical application on smart phones
  - Future development

Implementation Tool

- ONE simulator



Related work

- Primarily focus on two aspects:
- Theories
  - Develop or resolve new theoretical issues
    - Trilateration theory [4]
    - Quality of Localization [5]
    - Eliminating noisy and dynamic effects [6]
    - Self-adaptive routing algorithm [7]
    - Improve the measurement of distance ranging [6]
- Applications
  - Apply localization to static or semi-static environments
  - Apply localization to various areas:
    - Indoors [8, 9], transportation [10], health aids[11], Ocean geography [3], mining safety [12], monitoring pedestrians [11]

Conclusion

- Our contributions:
  - First propose the strategies for exploring maximum area with minimum loss algorithm based on localization theories
  - First apply localization techniques to a highly dynamic Mobile Ad Hoc Network (MANET)
  - Propose three design architectures

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