

Resilient Data Collection in Oil and Gas Refinery Sensor Networks

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**CYBER RESILIENT ENERGY
DELIVERY CONSORTIUM**

Motivating Refinery Resiliency

- Explosion of Italy's biggest refinery
- Our approach
 - Wireless sensor networks
 - Resilient data collection
 - Fast connectivity recovery

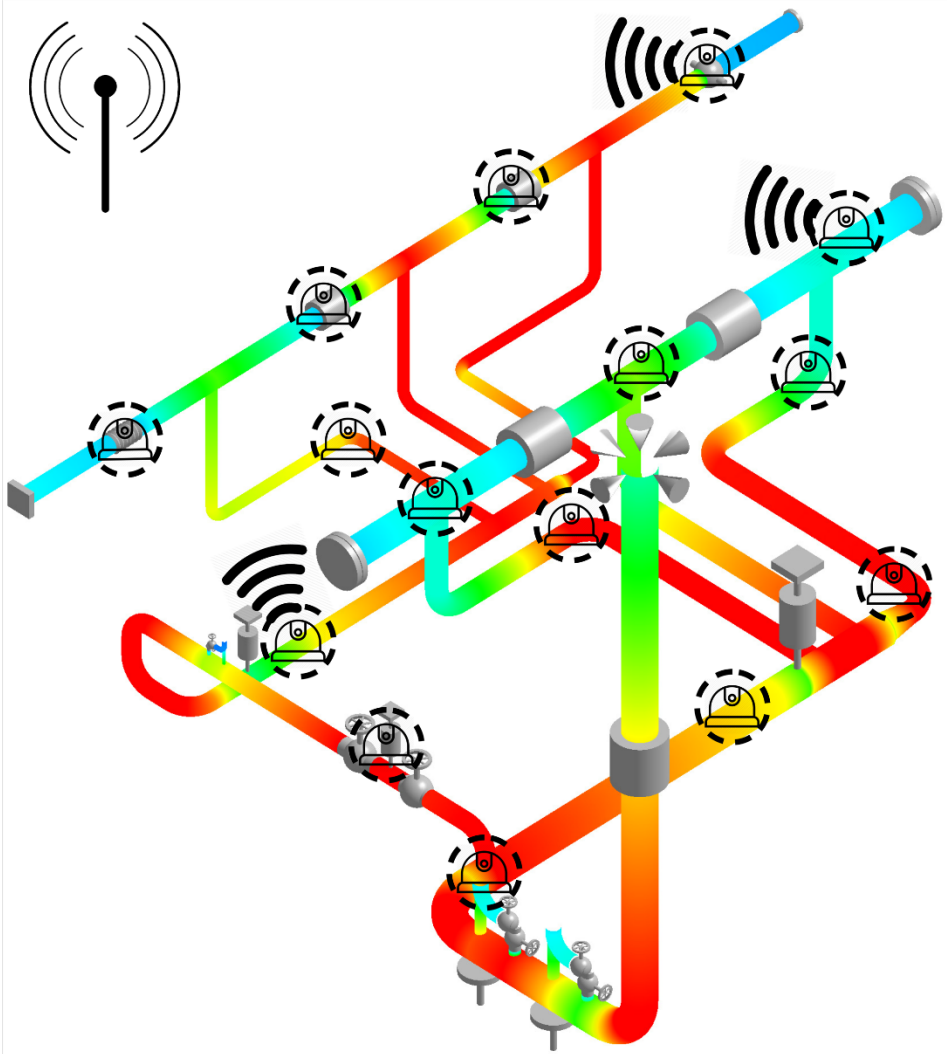


Problem Statement

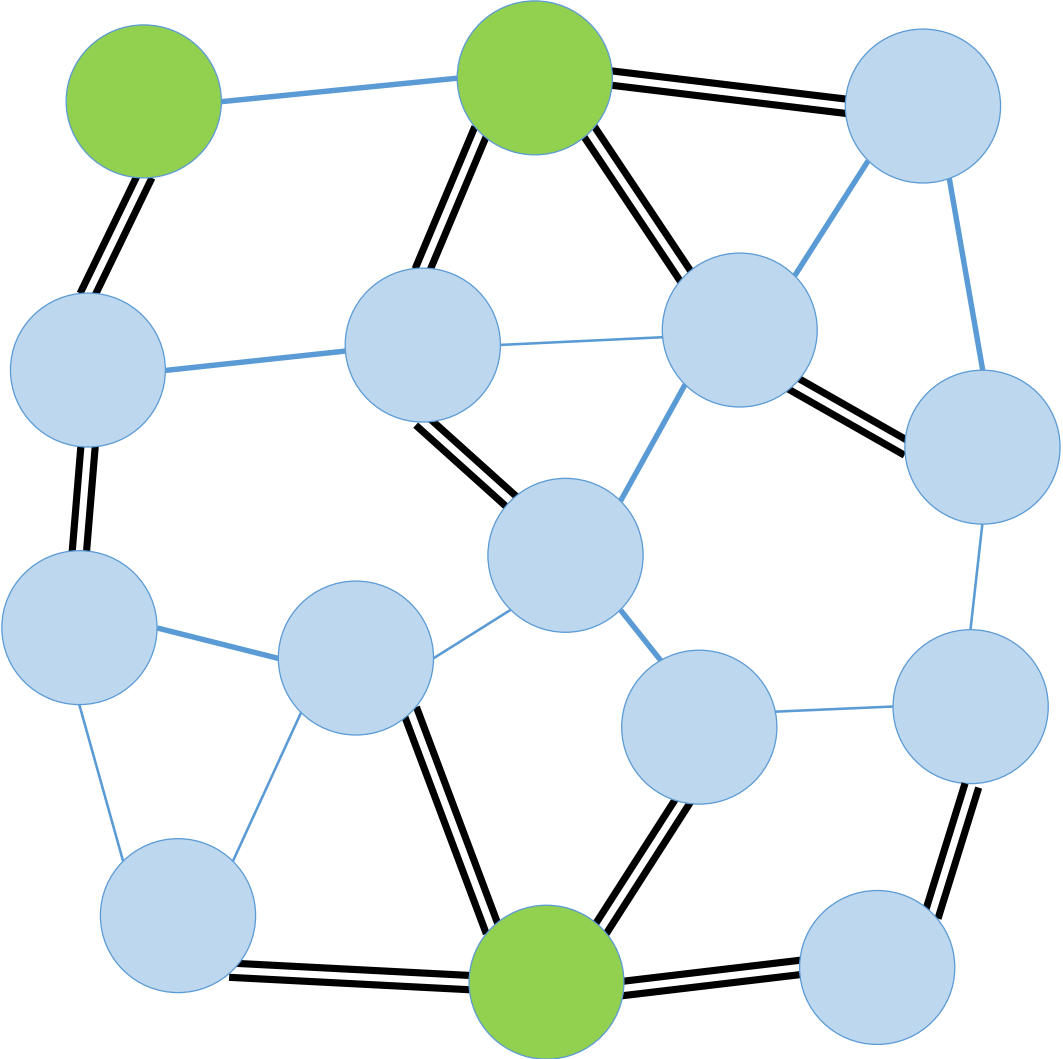


- 3D sensor placement
- Short-range v.s. long-range communication
- Multi-tree topology
- Large scale failures

Problem Statement



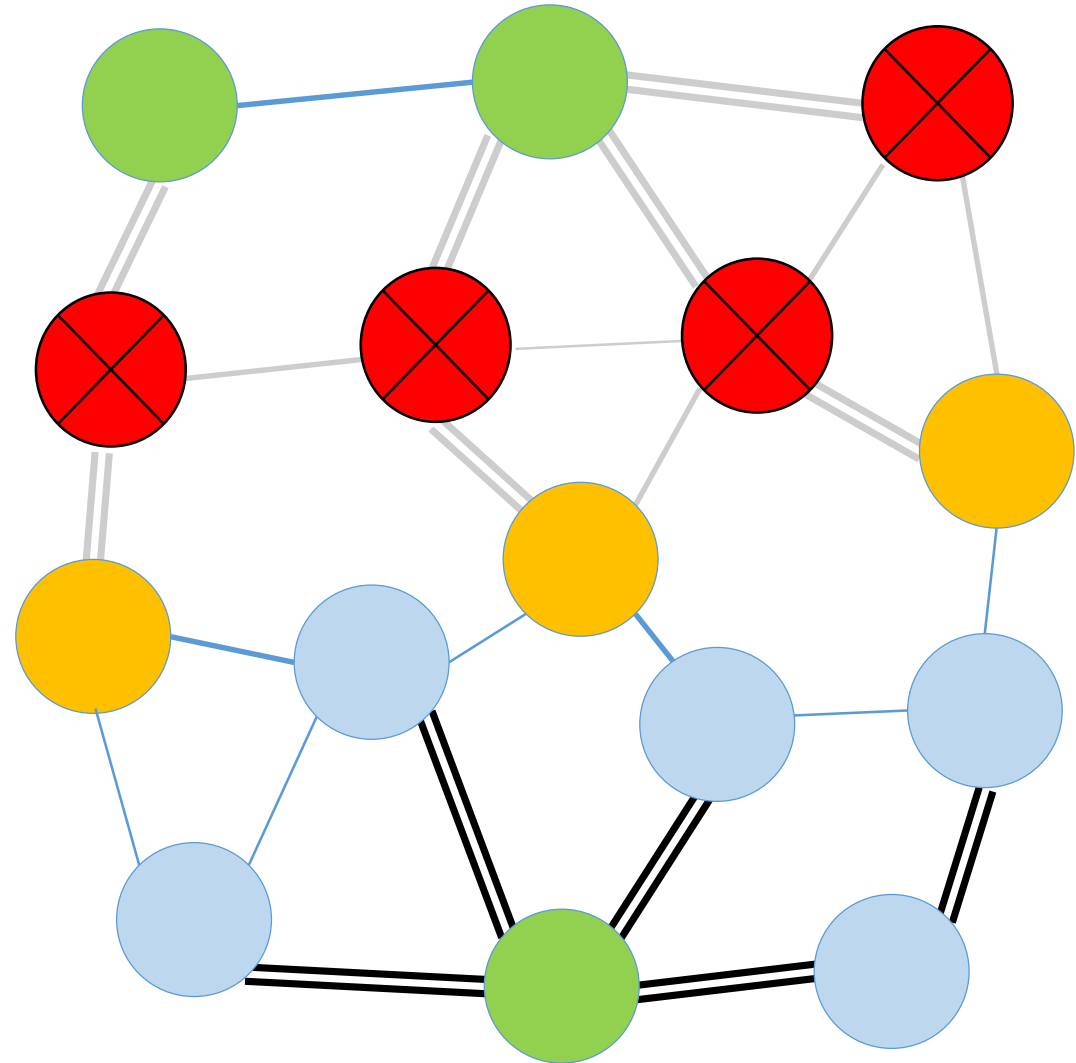
● Sensor Nodes with Short Range Communication == Tree Edges ● Root Nodes with Long Range Communication



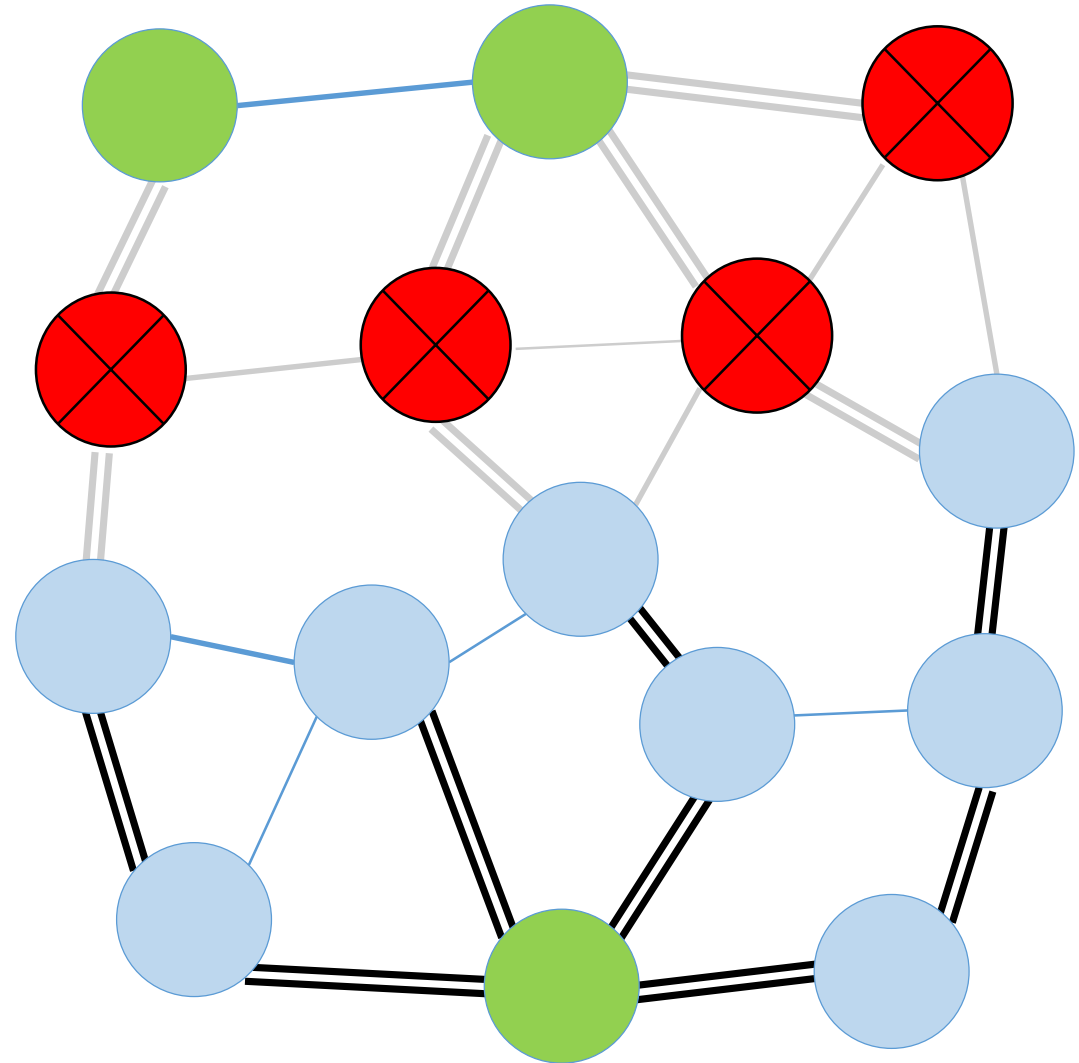
Problem Statement- Failure

Disconnected Nodes

Failed Nodes



Problem Statement – Recovery Goal



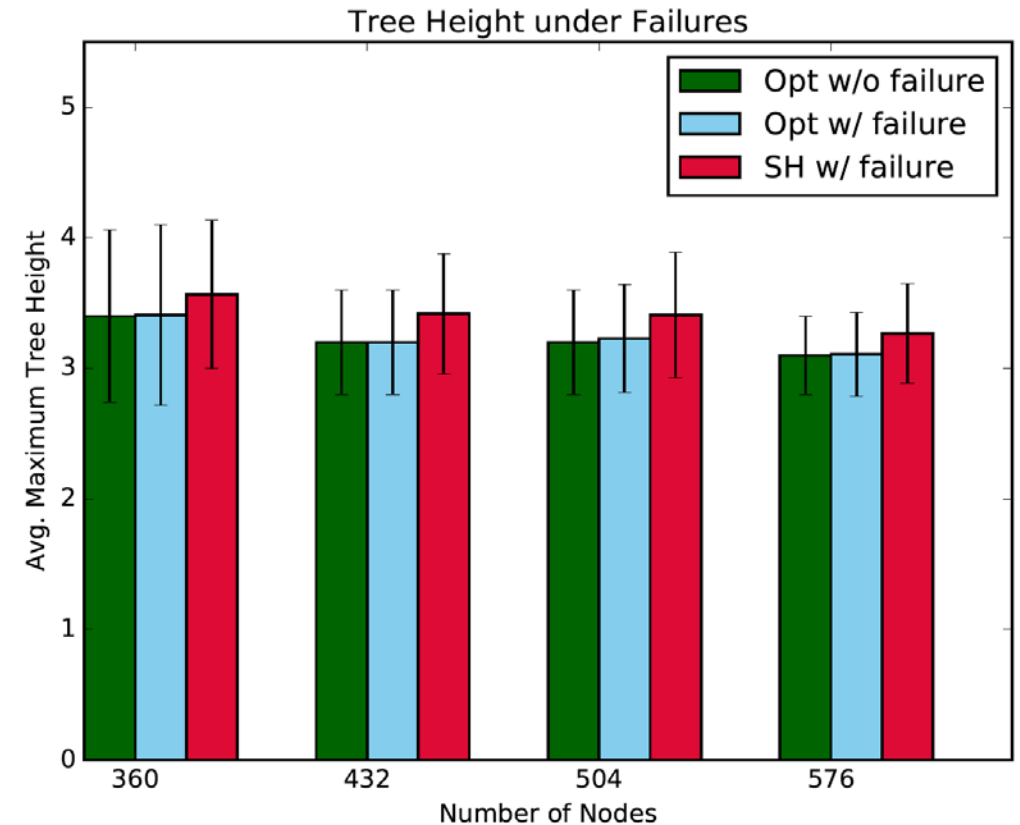
Recovery Solution

- Step 1: construct data collection trees
 - Centralized planning
 - Data collection time optimization
 - Key management and data integrity check embedded
- Step 2: recover connectivity under failures
 - Distributed self-healing protocol
 - Heuristic approach to re-construct backup data collection paths



Results

- Simulation with up to 500+ sensors
 - High success rate of recovery ($> 91\%$)
 - Low data collection time overhead ($< 7\%$)
- Prototype on Raspberry Pi 3
 - Low CPU utilization ($< 2\%$)
 - Fast path recovery ($< 5s$)



Next Steps - Questions

- **Interest in partnering with Industry Collaborator** who can work with us on this problem and provide **realistic use cases** in terms of
 - Sensor topologies
 - Actual sensor capabilities
 - Realistic communication capabilities between sensors
 - Protocols among sensors and between sensors and control center (e.g., DNP3 and Modbus, IEC 61850 that are used in smart grid)
- **Interest in simulated or emulated experiments** on real world refinery sensor topology and with real use cases to **develop a planning tool**
- **Interest in integration of different sensors at one place (array of things)** in refineries to enable richer contextual information and provide smarter and faster recovery protocols/algorithms
 - Consider heterogeneous measurement data (temperature, pressure, etc.)
 - Consider multi-level cyber-physical system security issues





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