Resilient Framework with Authentication, Key Management, and Data Collection for Energy Sensors in Energy Distribution Networks

Resilient Data Collection in Refinery Sensor Networks

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GOALS

- Design resilient data collection framework for refinery sensor networks which is
  - fast and scalable
  - secure in terms of data integrity and confidentiality
  - resilient under contingency, by ensuring data availability under large scale sensor failures

CHALLENGES AND SOLUTIONS

- When relay nodes fail in the refinery sensor network, some nodes lose connectivity to the control center. Therefore, a self-healing mechanism must restore network connectivity without centralized control.
- We consider a general framework where a group key is shared by multiple sensors. For this reason, the data collection structure must provide isolation to reduce the risk of key leakage.
- Computation for optimal tree reconstruction is costly and insufficiently responsive in a contingency situation. We design a heuristic approximation to minimize data collection time in self-healing.

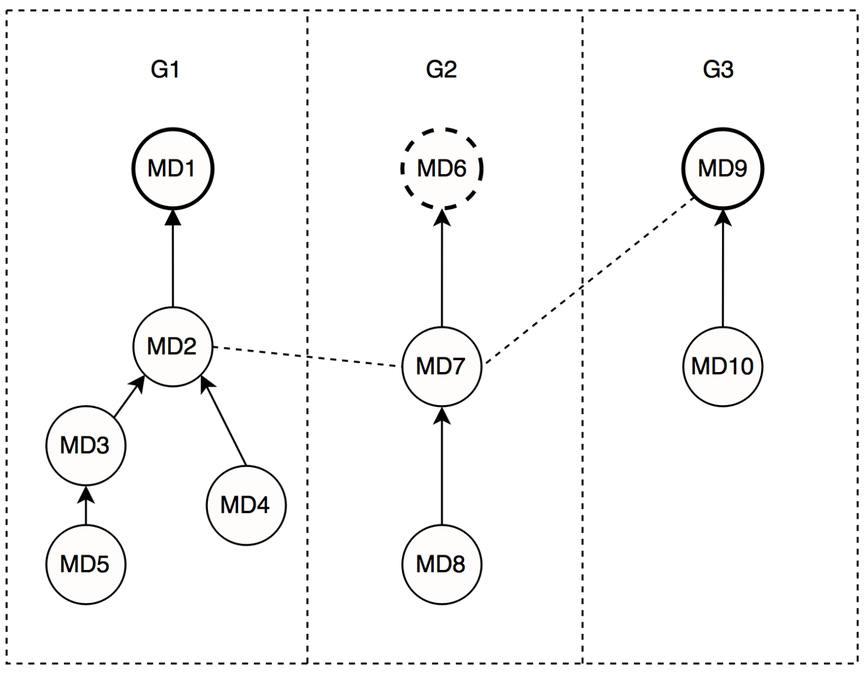

Fig 1. Data Collection Tree for Measurement Devices (MDs)

RESEARCH PLAN

- Design optimization metrics for data collection tree construction and formulate the Resilient Data Collection Tree Problem (RDCTP) using mixed-integer linear programming (MILP).
- Design the distributed self-healing protocol. The protocol restores network connectivity when large scale failure happens.
- Evaluate the self-healing protocol on refinery network topologies.
- Explore different failure patterns and network structures.

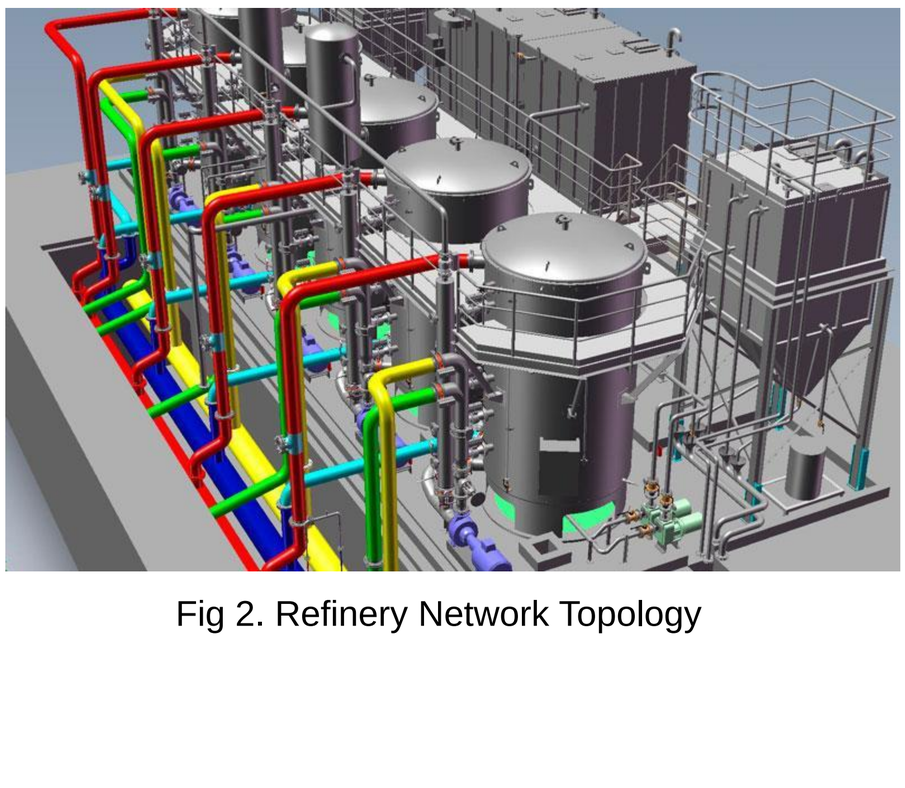

Fig 2. Refinery Network Topology

RESEARCH RESULTS

- Refinery network generation
  - Pipes with linear structure
  - Dense sensor deployment (avg. 50 ~ 80 neighbors)
- Failure injection
  - Inject 1,000 failure cases
  - Fail 2% of nodes simultaneously around a physical location
  - Evaluate failures that affect network connectivity
- Evaluation metrics
  - Recovery Success Rate: How likely the self-healing protocol can recover network connectivity.
  - Data Collection Time (measured by max. tree height): How much data collection overhead the self-healing protocol introduces compared with a fresh optimal reconstruction.

N_{node}	Success Rate
360	91.2%
432	92.1%
504	92.6%
576	93.0%

Table 1. Recovery Success Rate

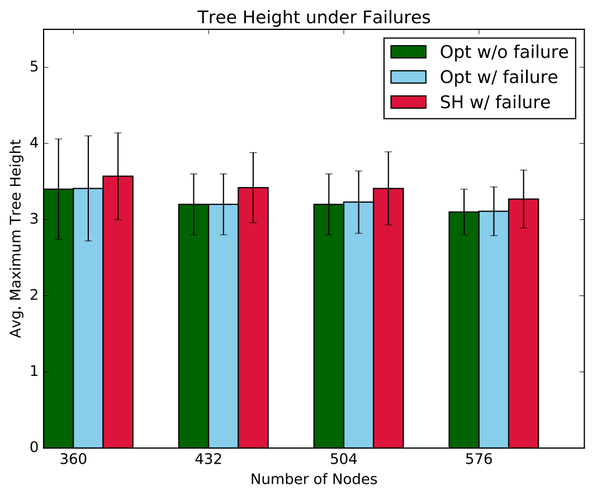

Fig 3. Data Collection Time

- Experimental results
  - The self-healing protocol is able to handle over 90% of the injected failures.
  - The data collection overhead of the self-healing protocol is about 7% compared to optimal reconstruction.

BROADER IMPACT AND COLLABORATION

- Publications
  - Tianyuan Liu, Hongpeng Guo, King-Shan Lui, Haiming jin, Klara Nahrstedt, “Resilient Data Collection in Oil and Gas Refinery Sensor Networks”, in preparation for ICCCN 2017.
- Collaborators
  - Shabbir Shamsuddin, Argonne National Laboratory

FUTURE EFFORTS

- Investigate other large scale failure patterns, e.g., sequential failure along the pipes.
- Explore energy-efficient data collection protocol to reduce the energy cost of unnecessary long-range wireless communication module.
- Measure the processing overhead of self-healing protocol.

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