State-Aware Decentralized Database Systems for the Smart Grid

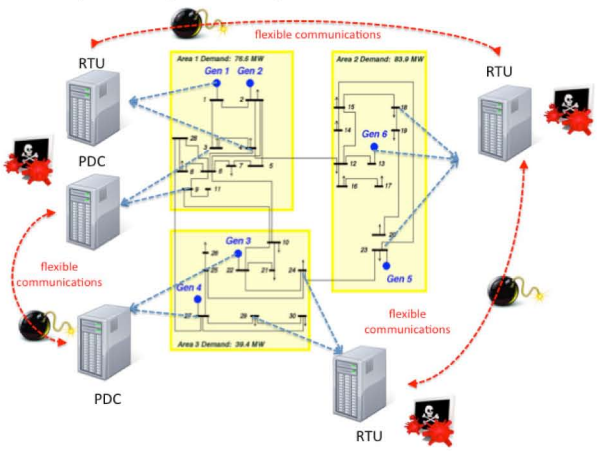
Decentralized Hybrid State Estimation for Power Systems and PMU Placement Design

Xiao Li, Zhifang Wang, Anna Scaglione

TCIPG

Goals

A **State-Aware Distributed Database (SA-DDBS)** architecture for data processing and management:



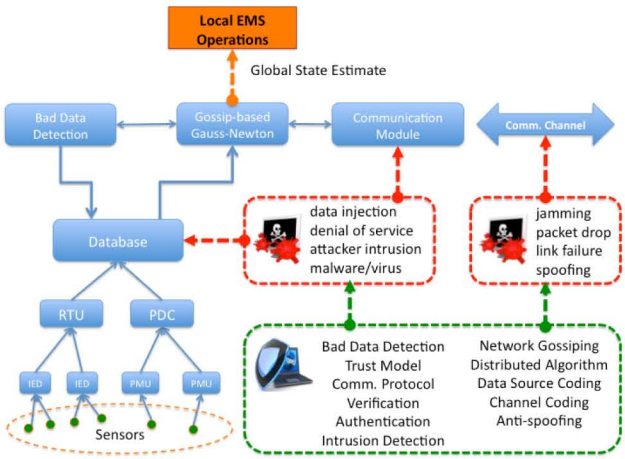
Key:

- Wide-area state awareness via decentralized state estimation.
- Optimization of the decentralized architecture to achieve **low complexity**, **fault tolerance**, and **flexibility**.
- Utilization of PMU devices to improve stability and accuracy.

Fundamental Questions/Challenges

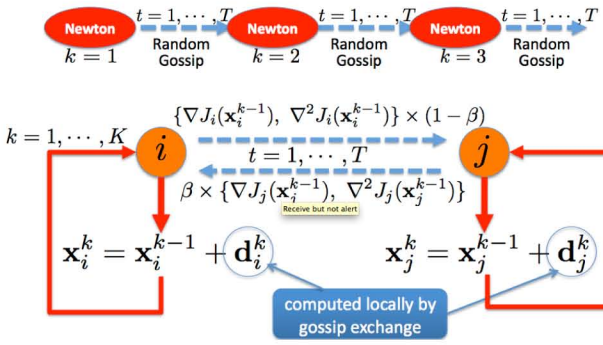
- Hierarchical approaches are not well matched to the robustness, flexibility, and security requirements of future power grids.
- How do we maintain a consistent and accurate state estimate across distributed control areas? What are the countermeasures for bad data?
- How is the accuracy related to the communications between DDBS?
- Who should talk to whom? What are the criteria for evaluating the trustworthiness of a peer?
- How do we design the communication protocol such that distributed architecture is robust to channel impairments, packet drops, or even link failures?

Research Plan

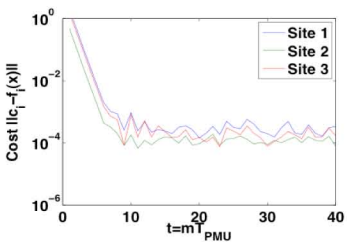


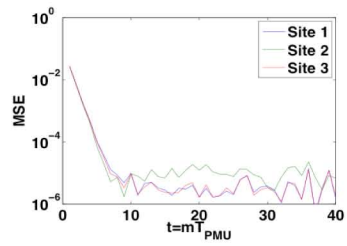
Research Results

- Proposed a Gossip-based Gauss-Newton (GGN) algorithm for decentralized state estimation using hybrid measurements from SCADA and WAM.
- Studied the effects of PMU placement on convergence and accuracy of the state estimation.
- Proposed optimal PMU placement schemes for state estimation.

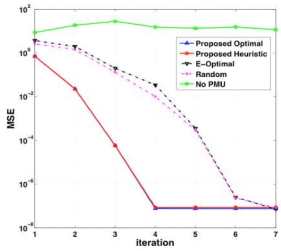


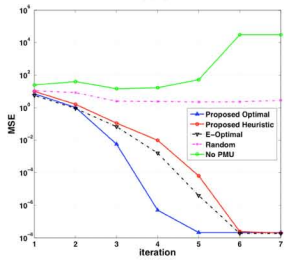
State Estimation Performance





Optimal PMU Placement





Broader Impact

The proposed SA-DDBS provides vast advantages in terms of:

- A security-aware gossiping protocol that prevents data injection, spoofing, and attacker intrusions.
- Scalability, resilience to link failures and server erasures, network delay, bandwidth usage, and storage efficiency.

It will provide enabling **just-in-time and just-in-place data delivery**, **with security taken into account**, for system-wide monitoring and operation, as well as wide-area preventive and restorative control.

Interaction with Other Projects

- Prof. Campbell, "Assessment and Forensics for Large-Scale Smart Grid Networks"

Future Efforts

- Data injection attack countermeasure.
- Trust assessment and modeling among DDBS.
- Protocol design to optimize accuracy and security.