Decentralized Sensor Networking Models and Primitives for Smart Grid: Part II

State-Aware Distributed Database Systems

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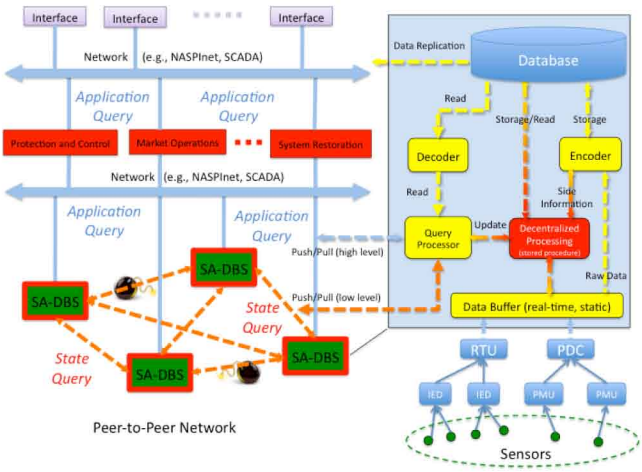
Goals

Enhanced measuring/monitoring systems can improve grid security and resilience. However, data management is a key problem: **how should one store, process, and deliver the measurement data to enable accurate and timely response to application queries?**

The key idea is to exploit the structure of the data and the class of queries that are typical of cyber-physical systems (CPS).

This project aims at:

- Streaming peer-to-peer architecture for computation, database storage, and management.
- Model-based data representation, storage, processing, and access.



Fundamental Questions/Challenges

- What is an appropriate scheme for expressing and storing the huge amount of data acquired in the Smart Grid (WAMS, SynchroPhasors, AMI)?
- Distributing computation, communication, and data management of the current system are interrelated and depend on network constraints.
- P2P architecture is not structurally matched to existing distributed state estimation (*flat* vs. *hierarchical*).
- Streaming P2P architecture that facilitates both database management and state computation is not explicitly defined in the literature.
- The way to replicate and manage data across wide areas for rapid and reliable access is not immediately clear.

Research Plan

Develop a new architecture for streaming P2P Database Systems (DBS) that is useful for Cyber-Physical Systems (CPS), coined "State-Aware" Distributed DBS (DDBS).

The SA-DDBS comprises:

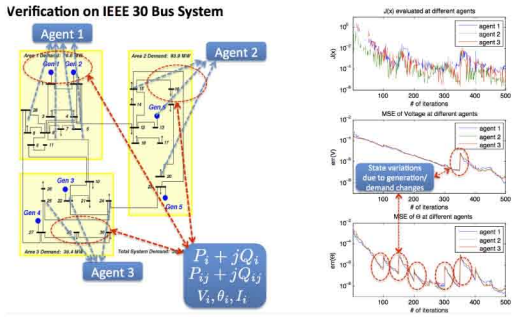
a) A stored routine for decentralized state estimation (G-SE Algorithm).

b) A representation and archival mechanism utilizing the stored routine.

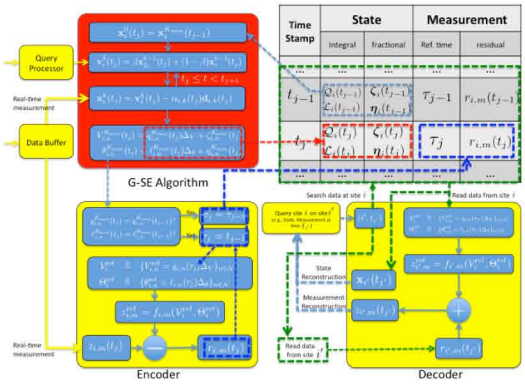
c) A reliable and flexible data replication mechanism.

Research Results

a) Initial experiment: decentralized state estimation via gossiping. We verified the effectiveness of the proposed P2P SA-DDBS, which leads to convergent estimates across the whole network with simply local communication and computations.



b) Developed a basic encoder/decoder model that utilizes the system state as side information to improve storage efficiency.



Broader Impact

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

- Scalability; resilience to link failures, server erasures; network delay; bandwidth usage; 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

- Lossless Compression of Synchrophasor Measurement Unit Archives – Ray Klump and Zeb Tate.
- Cooperative Congestion Control in Power Grid Communication Networks – Klara Nahrstedt and Naveen Cherukuri.
- Real-time Streaming Data Processing Engine for Embedded Systems – Ravi Iyer and Nithin Nakka.

Future Efforts

- Generalized distributed storage codes for SA-DDBS.
- Improve the performance of encoding/decoding strategy and data repair mechanism.
- Measure network delay and resilience to data attacks.
- Use data for vulnerability assessment.