Application Directions

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Cloud Computing for the Smart Grid

Current target:

- High-throughput data from SCADA and PMUs
- Cloud-based collection, processing, archival
- And access to public sources (NOAA, USGS)?

One goal: Faster/cheaper versions of current applications.
Question: What new applications does this enable?

Challenges

- Current clouds $\neq$ HPC clusters
  - More dynamic resource provisioning
  - Different failure model
  - High variance in effective latency
  - Good for pleasingly parallel vs. highly coupled
- High performance for coupled simulations is not trivial
  - See e.g. "Making Time-stepped Applications Tick in the Cloud" (SOCC 2011)
  - Trade-offs are evolving!

Killer apps?

- Grid radar: understand wide-area grid stress, disturbances
- Analysis apps: search past experiences, analyze current state, and explore "what-if" scenarios for future evolution
- Collaborative tools for operators
- Mining of realistic scenarios for education and research

Idea: Diagnostic Fingerprints

- Goal: Fast identification of relevant events
- Steady state fingerprints (now)
  - Measurement: Change in steady-state voltage
  - Events considered: Failure of one or two lines
  - Fingerprints derived computationally
- Transient fingerprints (next)
  - Measurement: Time-aligned windowed PMU transient data
  - Events considered: Line failures, problems in neighbors?
  - Fingerprints derived from computation or recordings

Steady state fingerprints

Concrete case: fingerprint for line failures in the network

- State: complex bus voltage vector v
- Fast observation: subset of voltage vector Ev
- Fingerprint: change $E\delta v$

Question: Can we find a line failure (ΔY) that explains $E\delta v$?

Steady state fingerprint test

Line (i, j) fails, $Y \mapsto Y + \Delta Y_{ij}$. Power flow equations:

$$A_{ij}\delta v \quad = \quad (A + U_{ij} C U_{ij}^T)\delta v \quad = \quad b_{ij} + O(\|\delta v\|^2)$$

where $U_{ij} \in \mathbb{R}^{n \times 4}$ and $b_{ij} \in \mathbb{R}^n$ are simple functions of (i, j).

Linearize in δv to get fingerprint:

- Fingerprint: $E\delta v_{ij} = EA_{ij}^{-1} b_{ij}$.
- Fingerprint distance: $t_{ij} = \|E\delta v_{ij} - \delta v\|$

Computing t_{ij} may require two linear solves with A. Can avoid with cheap lower bounds (filtering).

Fingerprints for Transient Analysis

- Transients travel through network.
- PMUs can observe transients, create a fingerprint.
- Use fingerprint to analyze transient.
  - Have I seen something like this before?
  - What is its likely effect?
  - How quickly will it transit to a neighboring operator?
- Goal: Fast lookup for data streaming from GridCloud

Summary

- A smart grid cloud offers interesting application opportunities
  - High capacity for pleasingly parallel analysis
  - Responsive apps based on offline/online work split
  - Fingerprints and grid radar are one idea
  - Opportunities for more data fusion, data-driven models
- Synergy between platform and app development at Cornell

Questions

We need help to make our work relevant!

- What apps will actually excite power engineers?
- What are the reliability and noise characteristics of PMUs?
- What are test cases (topologies, PMU deployments, etc)?

My student coming to ISO-NE in fall to further this discussion.