Towards More Effective & Resilient Power Apps Exploiting Better Comms. & Computation

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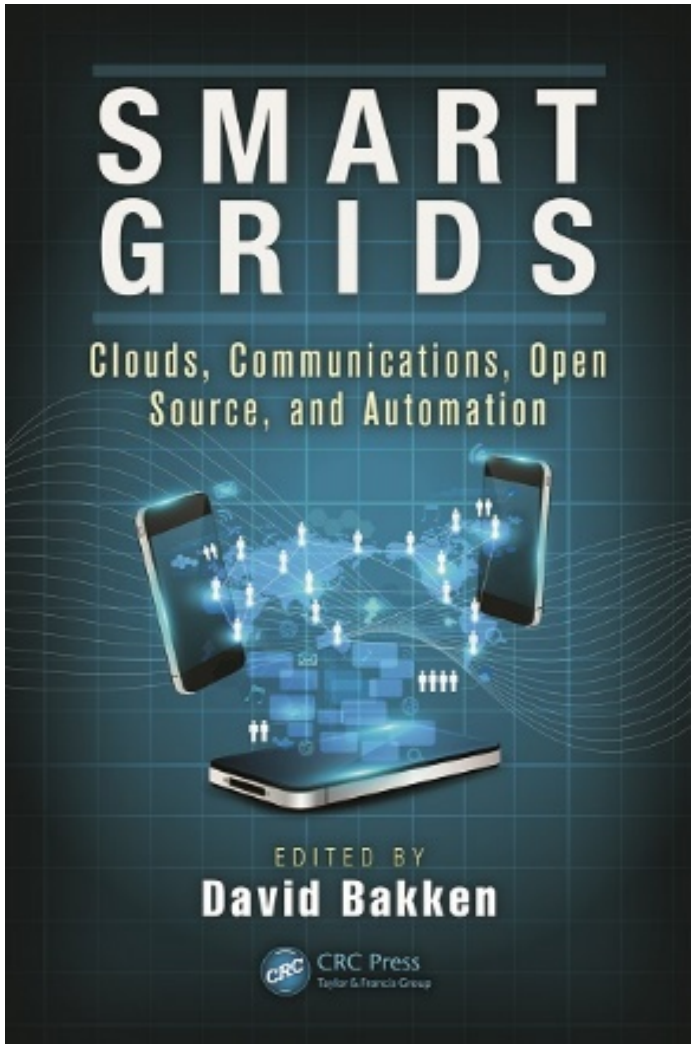
The Issue

- In the last 30 years the state of the art and practice has increased a LOT in
  - Computer networking
  - Distributed computing (esp. middleware & cloud)
- The way many power researchers write their programs has not leveraged these advances
- Outline of the talk
  - Summarize what the state of the art is
  - Pose questions power researchers can ask themselves to better utilize communications and computation

Context

- IANAPP (power person): Computer Scientist
  - Core background: fault-tolerant **distributed computing**
  - Research lab experience (BBN) with wide-area middleware with QoS, resilience, security, …. for DARPA/military
  - Working with Anjan Bose since 1999 on **wide-area** data delivery issues appropriate **for RAS and closed-loop applications**
    - **GridStat (1999-present)**
    - **GridSim (2009-2014)**
    - **GridCloud (2012-present)**



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gridstat.net

Comms Baseline: You Can Assume

- Data delivery over WAN **can** be (with GridStat etc):
  - Very **fast**: less than ~1 msec added to the underlying network layers across an entire grid
  - Very **available**: think in terms of up to 5+ 9s (multiple redundant paths, each with the low latency guarantees)
    - **Even in the presence of failures!**
  - Very **cyber-secure**: for long-lived embedded devices and won't add too much to the low latencies
    - E.g., RSA adds >>60 msec so not for RAS or closed-loop
    - Shared keys (61850-90-5): subscriber can spoof publisher ☹
    - GridStat solution not vulnerable and only adds ~1msec
  - Tightly **managed** for **very strong guarantees** (~~MPLS~~)
  - **Adaptive**: can change pre-computed subscriptions ~INSTANTLY (and dynamic requests FAST)

Questions to Ask Yourself

- So how can power researchers exploit this better communications infrastructure?
- What **rate** and **latency** and **data availability** does my power app *really* need for remote data?
  - Why fundamentally does it need that?
  - How sensitive is it to occasional longer delays, periodic drops (maybe a few in a row), or data blackouts for longer periods of time?
- Can I formulate and test hypotheses for the above?

Beyond Steady-State-Only Thinking

- Previous is just for steady state: different in some contingency/mode situations?
- What extra data feeds (or higher rates etc) could I use in a contingency/mode (could get in << 1sec)
- How important is my app *in that given contingency/mode, compared to other apps?*
  - E.g., simple "importance" number [0,10]
  - How much worse QoS+ (latency, rate, availability) can I live with in steady state and in given contingencies?
    - But would **still get strong guarantees** at that lower quality
    - How much benefit do different levels really give me?
  - Can I program my app to run at different rates, or is there a fundamental reason it has to run at one?

Bad Data

- How vulnerable is my power app to bad data?
  - State estimation obviously has handed for many decades
- But
  - How much bad data
  - Does how much bad
  - In what (power) circumstances?
- E.g. can I specify assumptions about bad data?
  - Number: absolute or (better) as a function of the problem size (state/configuration/#PMUs/etc)
  - Location and timing: randomly distributed or worst case?
  - Error degree: randomly off (what probability distribution) or worst case (from an adversary)?

Bad Manners

- How vulnerable is my power app or RAS scheme or stability assumptions to worst-case malicious behavior?
- E.g. not just false data (which may be able to be detected) but taking over command of a relay or other devices
  - How many of these, and of what kind, could cause problems?
- Thinking cyber-physical here
  - What are some worst case combinations of a physical attack (rifle, chaff, modifying sensors, ..) and a cyber attack (colluding customer meters, taking over relays, DDOS to throttle delivery of sensor data and commands,
  - And worst case under what situations?

Bad Manners (cont.)

- "The event I fear most is a physical attack in a successful cyber-attack in conjunction with responders' 911 system or *on the power grid*,"
  - Ronald Dick, director of the FBI's National Infrastructure Protection Center, *Washington Post*, Front Page Article, June 27 2002, (*emphasis* added)

A Cloudy Forecast

- What could I do with cloud computing, assuming it is made mission critical, i.e.:
  - Keeps same fast throughput
  - Does not allow deliberate "inconsistencies"
    - e.g., a replica does a state update never received by others
  - Is much more predictable with CPU perf., ramp-up time, …
  - (BTW, ARPA-E GridCloud proj. w/Cornell+WSU doing for >2 years)
    - Pilot starting with ISO-New England, likely others soon
  - **Not all CPUs in datacenter, some (managed) in substations… (Cisco Fog?)**
- How could I use
  - Tens/Hundreds of processors in steady state
  - **>>Thousands when approaching/reaching contingencies**
  - Data from ALL participants in a grid enabled quickly when approaching a crisis

CIP-Managed Compute+Comms+Security

- Computations + communications + security *can* be
  - Mission critical to power grid specs
    - Closed-loop WAN app requirements **WAY harder** than air traffic control, railways, military, …
  - Changed rapidly in a coordinated manner
    - Providing app developers **much higher-level building blocks**
  - Managed in a network operations center 24x7
    - **Much like a power control center!!!**
    - Needed if power grid stability really does depend on comms and computation and cyber-security
    - No more hard-coded and unmonitored comms infrastructures causing headaches when glitches occur!

Sources of Info (1)

- D. Bakken, A. Bose, C. Hauser, D. Whitehead, and G. Zweigle. "Smart Generation and Transmission with Coherent, Real-Time Data. *Proceedings of the IEEE*, 99(6), June 2011.
- David E. Bakken, Richard E. Schantz, and Richard D. Tucker. "Smart Grid Communications: QoS Stovepipes or QoS Interoperability", in *Proceedings of Grid-Interop 2009*, GridWise Architecture Council, Denver, Colorado, November 17-19, 2009. Online http://gridstat.net/publications/TR-GS-013.pdf.
  - **Best Paper Award for "Connectivity" track**. This is the official communications/interoperability meeting for the pseudo-official "smart grid" community in the USA, namely DoE/GridWise and NIST/SmartGrid.

Sources of Info (2)

- ToSG-Workshop.org
- Chapters in D. Bakken and K. Iniewski, ed. *Smart Grids: Clouds, Communications, Open Source, and Automation,* CRC Press, May 2014, ISBN 9781482206111.
  - G. Zweigle, “Emerging Wide-Area Power Applications with Mission Critical Data Delivery Requirements”.
  - D. Bakken *et. al*. “GridStat: High Availability, Low Latency and Adaptive Sensor Data Delivery for Smart Generation and Transmission.”
  - T. Gamage *et. al*. “Power Application Possibilities with Mission Critical Cloud Computing.”