GridStat
Middleware for More Extensible and Resilient Status Dissemination for the Electric Power Grid

Professors: David E. Bakken, Anjan Bose, Carl Hauser

Students: Ioanna Dionysiou, Kjell “Harald” Gjermundrød, Sudipto Bhowmik, Thomas Evje

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GridStat Collaborations & Sponsors

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• Dr. Howard Lipson and Dr. David Fisher, CMU CERT, GridStat Integration with Easel Simulation environment
• Prof. Ken Birman and Fred Schneider, Cornell, former PSERC grant (grid communications)
• **GridStat is work in progress….**
Outline of Presentation

• **Power grid today**
• GridStat Architectural Overview
• GridStat and Quality of Service (QoS)
Power Grid Today

• Three fundamental roles in the power grid:
  1. Generation
  2. Transmission
  3. Distribution

• Traditionally owned by a single, vertically-integrated company
  – Based largely on geography
  – Hierarchical infrastructure
  – Communications network is
    • Hardwired
    • Dedicated
    • Slow

• Everything is hard-coded based on this fixed hierarchy
  – Application programs
  – Status information
  – Control decisions
Components of the Power Grid

- **Generator**: generates power, based on requirements given by the grid.
- **Substation**: point of monitoring and control in the grid.
  - Can service many generators, and/or other functions
    - Distribution point to customers
    - Voltage boosting
    - Control functions
  - Generally only services one fundamental role
  - Always involved in control based on status of a lot of devices
- **Control area**: a set of substations
  - Geographic area ranging from a county in US to a few states
  - Services all three fundamental role
  - Is roughly equivalent to one or a few utility companies (most 1:1)
  - Collects status info from all substations for control decisions
- **Grid**: a set of control areas which are synchronously controlled
  - AKA “regional reliability council”, or “region”
Major Components of the Grid [NSTAC]

- **Generation**
  - Wind
  - Coal
  - Hydroelectric

- **Transmission**
  - ISO
  - Traders
  - Monitoring and Trading Services
  - Transmission Substation
  - Subtransmission Substation

- **Distribution**
  - Distribution Substation
  - Residential
  - Commercial
  - Industrial

- **Customers**
  - (Create load)
Grids in Canada and the US
ISO and Grid Security

- **Independent System Operator (ISO):** new layer above the control area layer currently being added
  - A small number of ISOs for bigger grids

- ISO is responsible for **grid security**
  - Means no actions being considered, or any probable contingency, can lead to a blackout or brownout
  - Roughly translates to what computer scientists would consider stability and reliability

- Grid security is an online, real-time activity
  - ISO monitors status from all control areas
  - Receives all status info from any control area or substation in its jurisdiction

- ISO’s functionality used to be performed by the vertically-integrated utilities
  - Now too much power flowing across them or around them
Status Information & the Power Grid

• Deregulation (of generation) is adding many more participants to the grid!

• Resulting changes in status monitoring requirements
  – Many more devices with intelligence
  – More general topology and connectivity
  – Much more heterogeneity involved
  – Existing hardwired, hierarchical structure does not suffice!

• New services require more quantity, timeliness, …
  – Local extreme today: substations tracks all its devices
  – Other extreme possible: adjacent grids track some of neighbors’ internal status or derived (computed) values

• Workarounds beginning
  – Use internet technologies with existing ISPs, on best-effort basis
  – Would love to have their own ISPs with specialized communications services and achievable survivability, if shown the way…
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GridStat

• Status dissemination middleware tailored for the power grid
  – Collaborative project with EE and CS at WSU, others
  – Could be used for other critical infrastructures

• Publish-subscribe architecture
  – Simple, CORBA-compliant APIs for both publishers and subscribers
  – Subscribers have transparent cache of latest value
  – Network of internal servers managed for QoS
GridStat (cont.)

• QoS properties
  – timeliness
  – fault tolerance
  – security

• Optimizations and management will take advantage of
  – Semantics of status events
  – QoS requirements

• Need to integrate different viewpoints:
  – Publish-subscribe logical view
  – Hierarchy of QoS controls
  – Physical info and power flow
GridStat Architecture
Point of view: Publish-Subscribe with Hierarchical QoS Managers
Point of view: Logical Publish-Subscribe
Sample Admission Control Graph

Trader 1

0.2/0.4

0.2/0.3

8

10

0.2/0.3

0.1/0.3

9

0.1/0.3

0.1/0.3

11

0.3/0.5

12

0.7/0.9

Link Delay Transmission

Link Delay Transmission with Encryption

13

14

0.1/0.3

0.1/0.3

0.2/0.4

0.2/0.4

Trader 2

Power Station 2

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GridStat–16
GridStat Subscribers Caches

Server

Status 1

Subscriber 1

Status 1

cache 1

Server

Status 2

Status 2

cache 2

Server

Status 3

Status 3

...
Attributes of Status Items

• A status item has the following attributes (initial set):
  – value (of type bool or int or float)
  – moving_average(t)
  – change_rate
  – change_rate_moving_average(t)
  – max(t), min(t)

• Static attributes
  – name
  – principal (user/owner) of publisher
  – …. probably more
Compound Status Items

- Created dynamically from existing status items and their attributes
  - Creates a new, first-class status item
  - Can be published, reused, managed...
- Can be the usual types for its value
  - boolean, float, int
  - type unrelated to underlying value types: can construct a bool from two floats etc.
Condensation Functions

- Sometimes subscribers just read a large set of status items once to calculate a derived variable.
- Support by allowing user-defined condensation functions to be loaded in GridStat servers.
  - Typically close to publishers.
- Note: condensation functions may obsolete compound status items (open research question).
  - And my voting middleware could be used for condensation!
GridStat Status Patterns

• Goals: give building blocks useable by non-CS specialists to create common status items
  – Try to capture status semantics + some QoS info

• Initial examples
  – **Boolean**: Failure detector or circuit breaker
    • Values in intermediate servers can cancel out
  – **Periodic**: Sends float or int value periodically
    • Can be dropped downstream if nobody needs it in the near future and has a recent enough one
  – **Alert**: Potentially catastrophic situation
    • Propagate to subscribers immediately, from highest priority to lowest
    • Deliver by Callback (not just cache update)
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Overview of GridStat and QoS

- QoS requirements/preferences/metadata captured from multiple entities
  - Subscriber
  - Publisher
  - QoS Manager
- QoS properties
  - Fault Tolerance
  - Timeliness
  - Security
    - Integrity
    - Confidentiality
  - Priority
    - To be used mainly when above properties cannot be delivered
GridStat QoS Entities

• Subscriber
  – Widest varieties of QoS requirements & specs
  – Specifies what it desires and can fall back to

• Publisher
  – Rate(s) of pushing updates of status item into the system
  – Sometimes access restrictions
  – Publisher knows little else about how its status is used!

• QoS Manager
  – Can override above settings by subscriber and publisher
### Initial QoS specifications

<table>
<thead>
<tr>
<th>Who sets what</th>
<th>Publisher</th>
<th>Subscriber</th>
<th>QoS manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redundancy (space)</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Delivery rate</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Delivery timeliness</td>
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<td></td>
<td>✓</td>
</tr>
<tr>
<td>Publisher rate</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Priority</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Confidentiality</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Integrity</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Access Control</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

**Note:** QoS Manager can override Publishers and Subscribers specifications
Related Work

- PASS (BBN/Gatech ICDCS ’99 Zinky/O’Brien/Bakken/…)
- Sienna (U. Colorado): content-based publish-subscribe
- InfoPipes (GaTech): fresh delivery of status info
- SpinGlass/Astrolabe (Cornell): scaleable multicast
Status

- Finished: Centralized publish-subscribe middleware with
  - one QoS Manager
  - publisher delivery rate QoS requirement satisfied
Status (cont.)

• Under development: Distributed publish-subscribe prototype with
  – multiple QoS Managers
  – redundant paths and best effort delivery
  – expected delivery date: June 2002
Other Related Work

• Development of a query language (ApproXPath) using XML for handling irregular data by supporting inexact (and exact) searches

• Simulation studies of the distributed information structure of the power system (can the real-time requirements be met by distributed system architectures?)

• Definition and documentation of QoS parameters necessary for wide-area power grid control and status dissemination

• Quantification of the requirements/effects of communication delays in the traditional Automatic Generation Control scheme
Future Work

• Integration with bandwidth reservation
• Easel simulation language
Conclusions

• GridStat is publish-subscribe middleware
  – Optimized for the power grid
  – Providing QoS: timeliness, fault tolerance, security
  – With CORBA-Compliant APIs for heterogeneous operation
  – Clients get transparent cache of latest value