WASHINGTON STATE UNIVERSITY

School of Electrical Engineering
and Computer Science

GridStat

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

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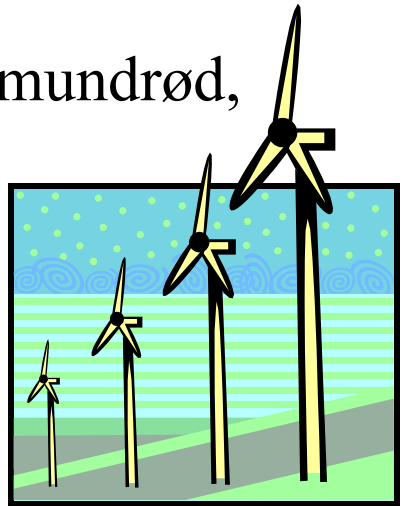

GridStat Collaborations & Sponsors

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- Prof. Kevin Tomsovic, WSU, grid control with varying feedback loops and varying time horizons
- Prof. Curtis Dyreson, WSU, metadata for power grid status, temporal queries over status information
- 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)

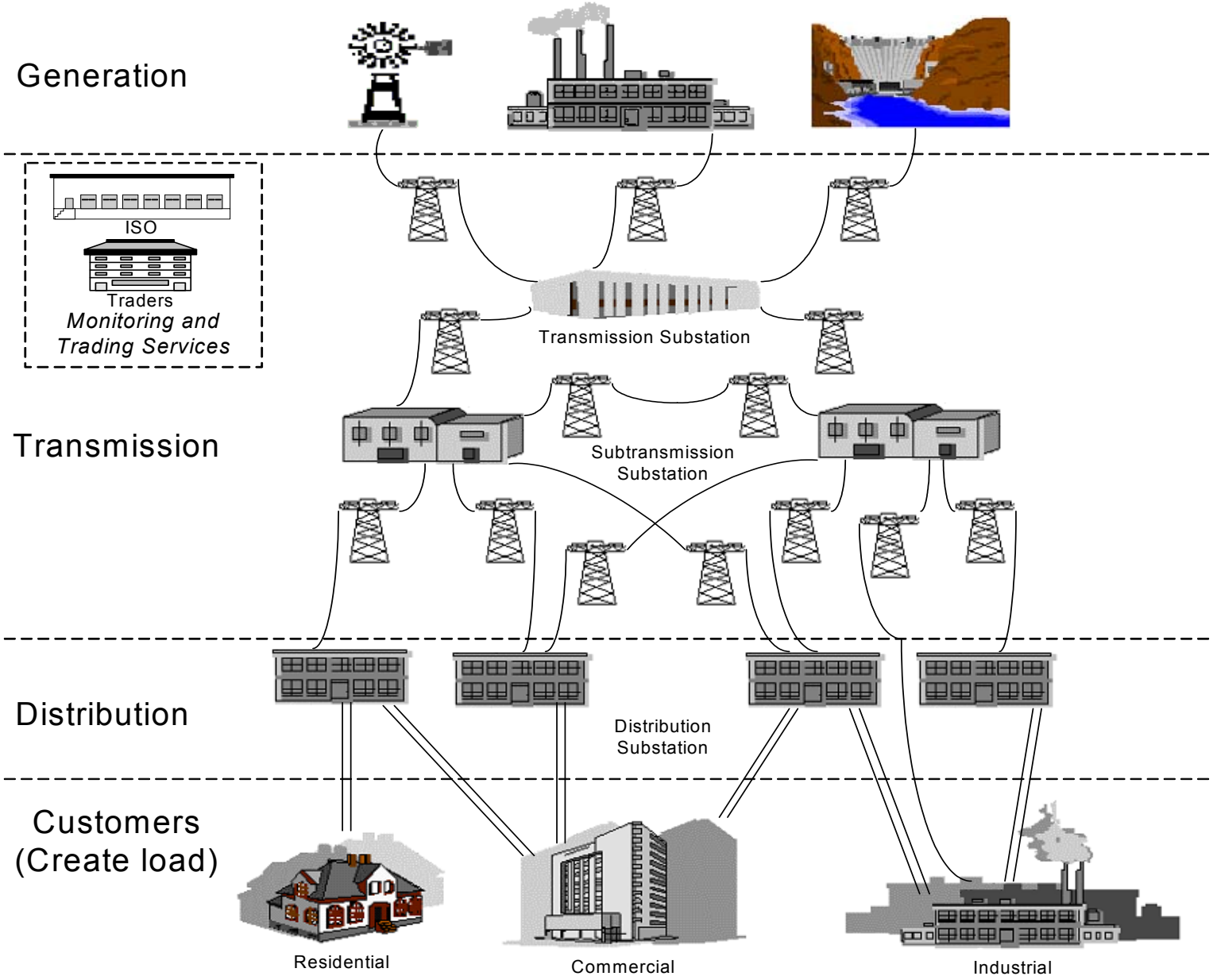
Power Grid Today

- 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

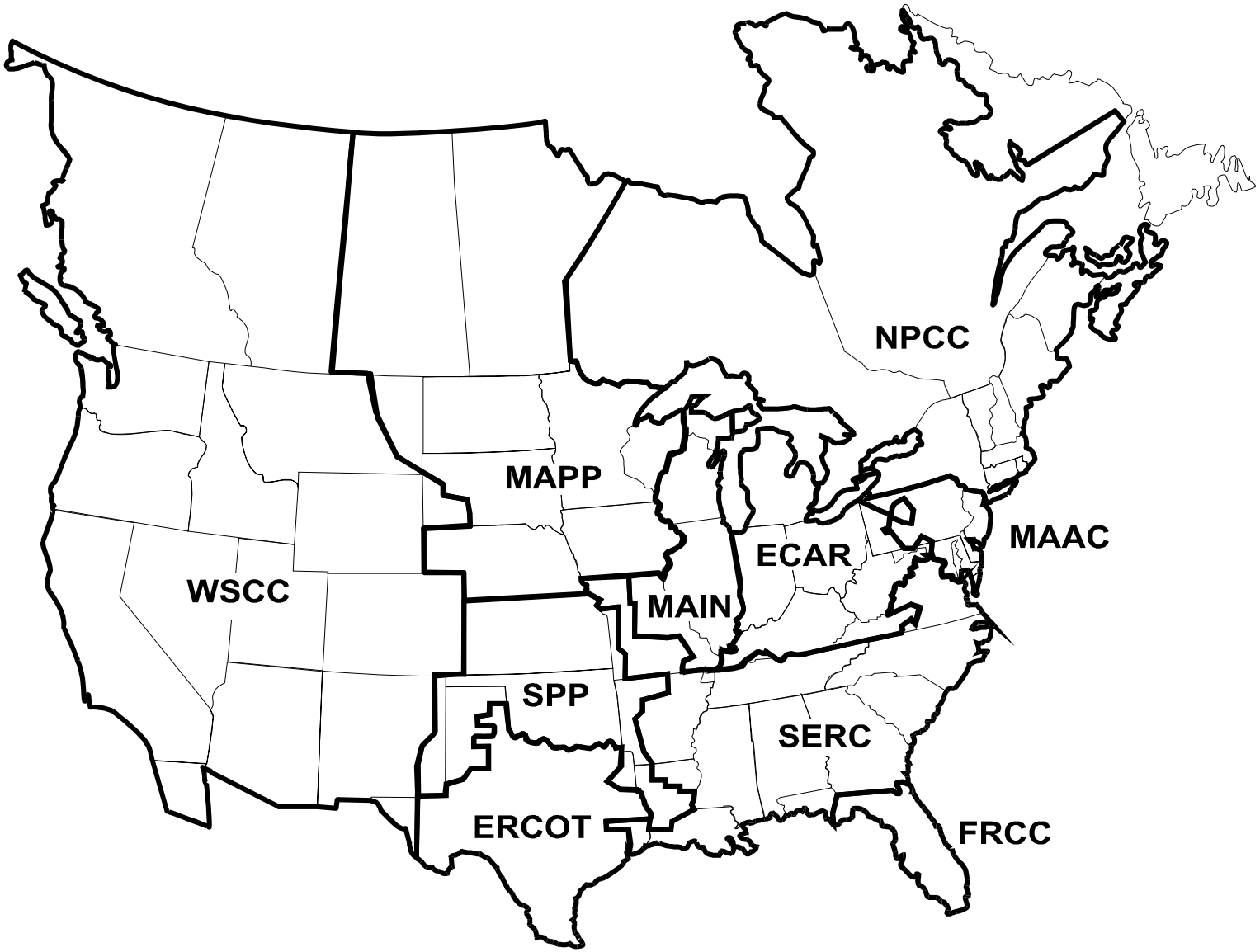
Components of the Power Grid

- **Generator**: generates power, based on requirements given it
- **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]



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 <u>all</u> 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 and Quality of Service (QoS)

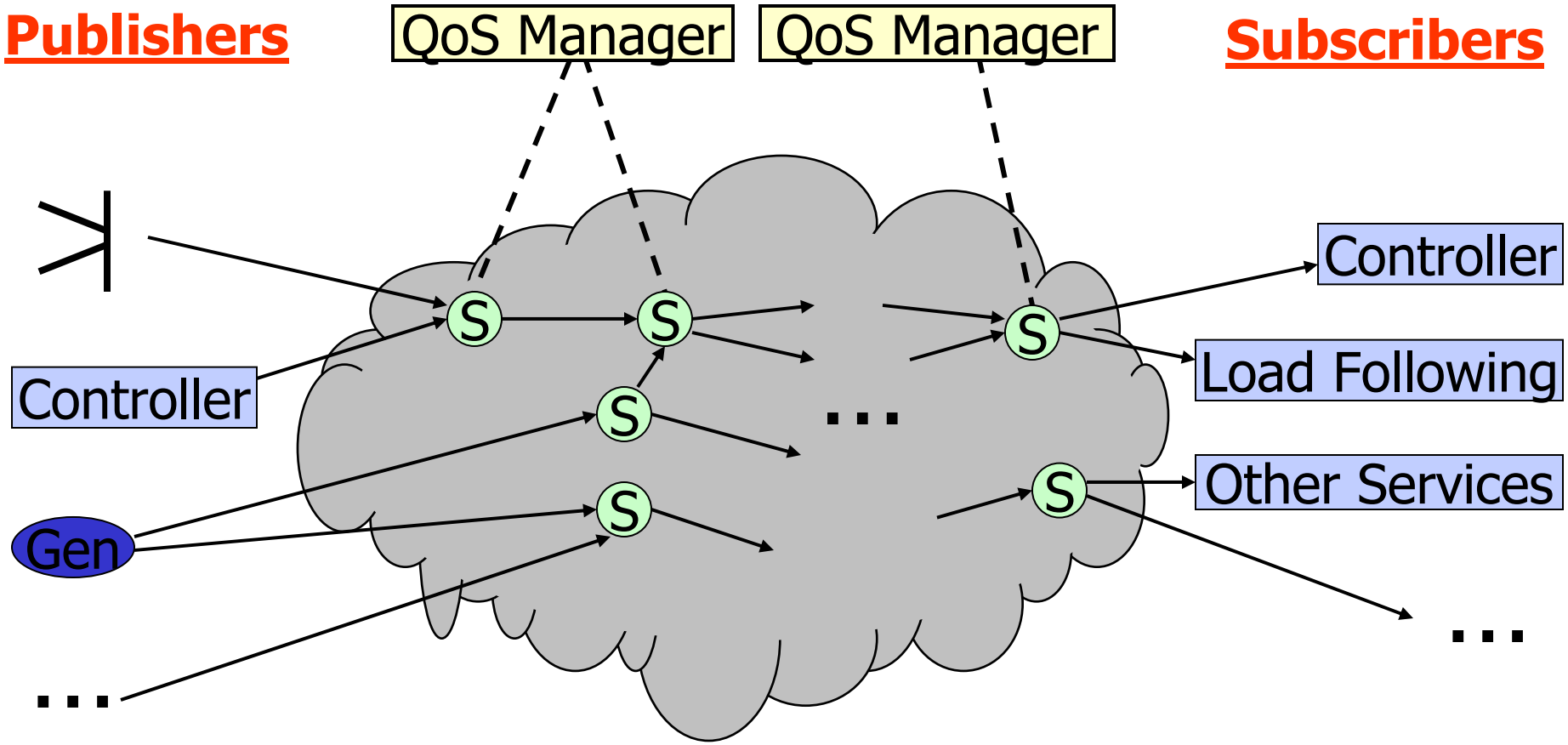
GridStat

- **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

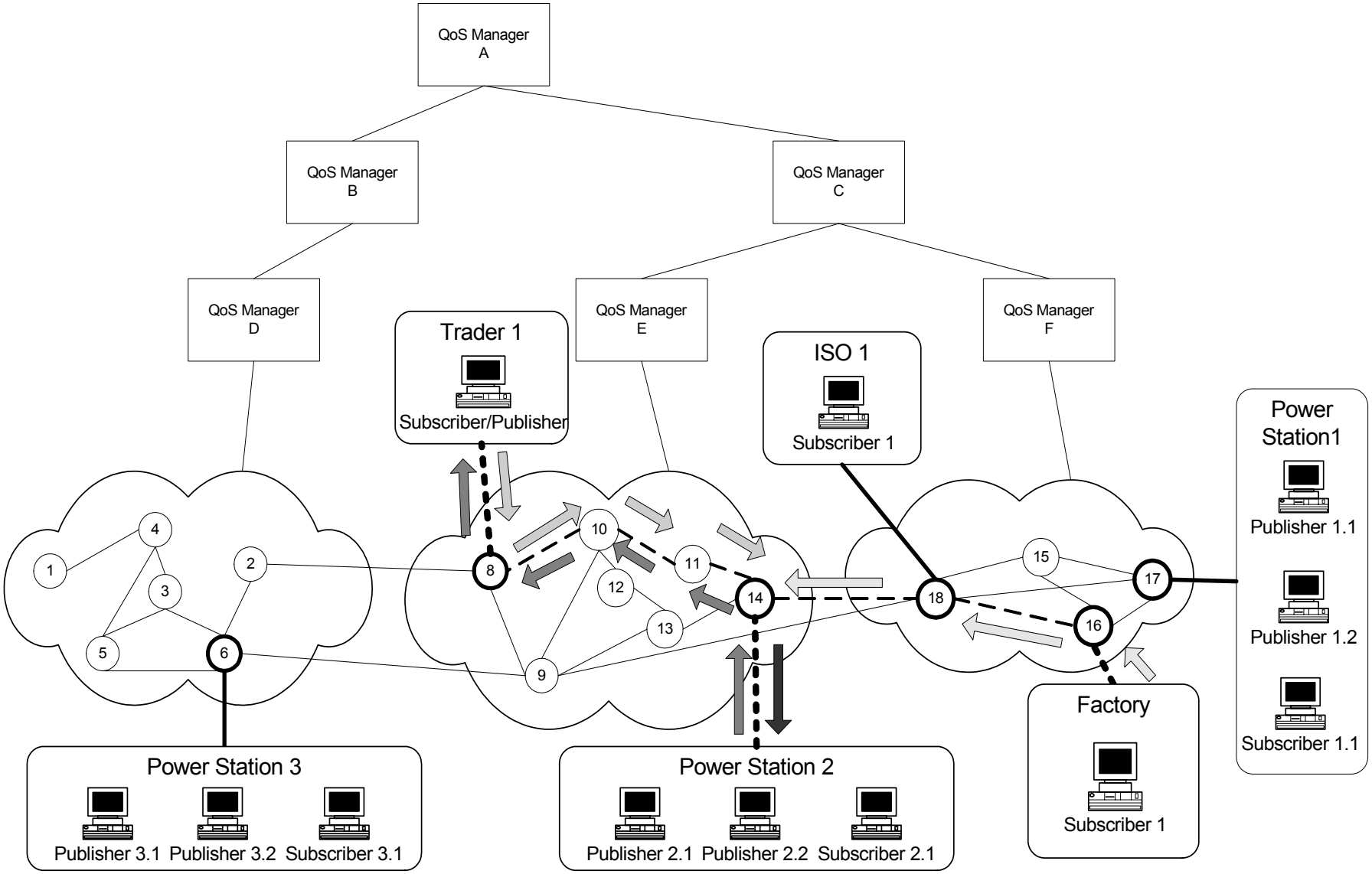
GridStat (cont.)

- 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

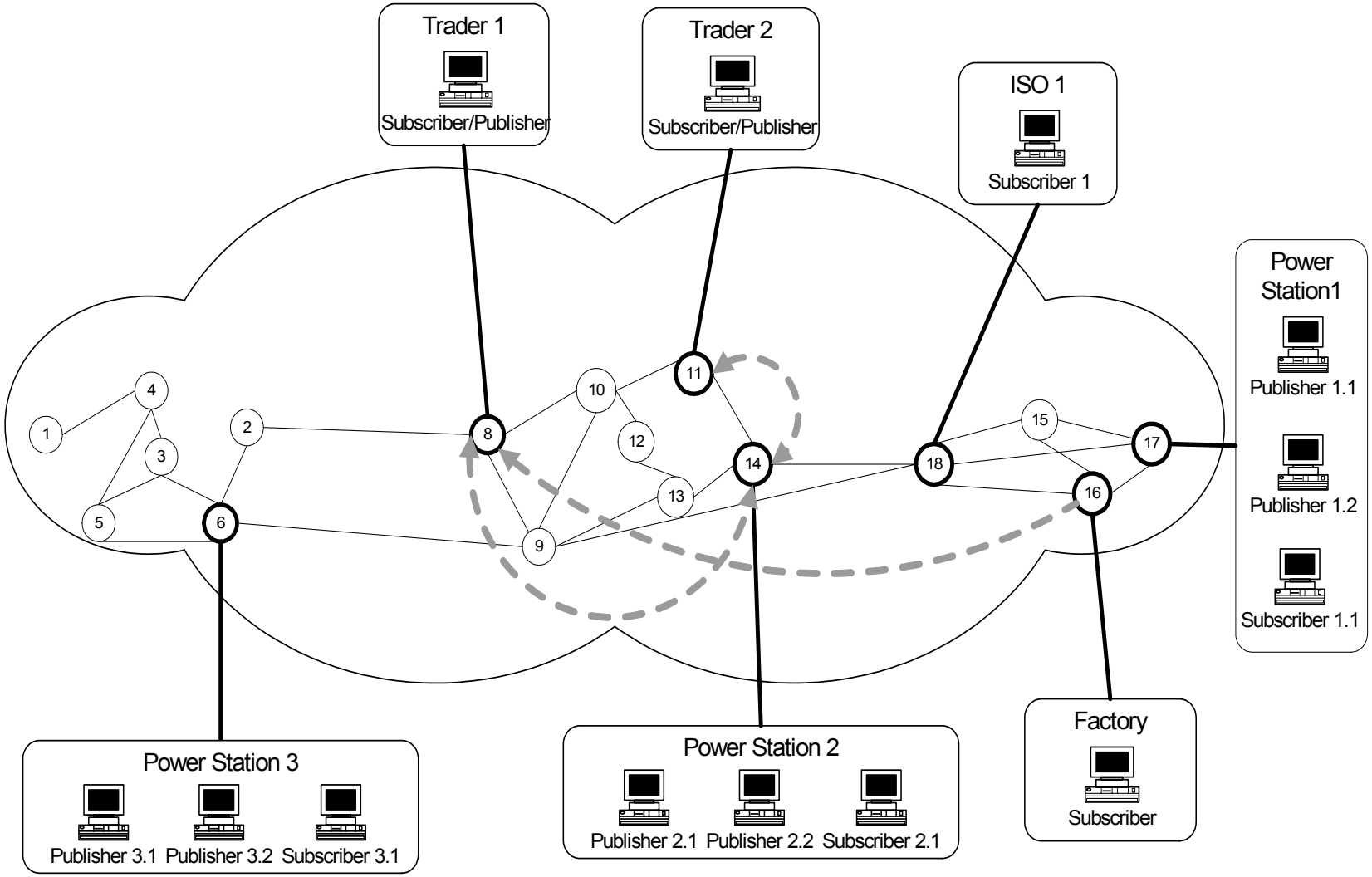
GridStat Architecture



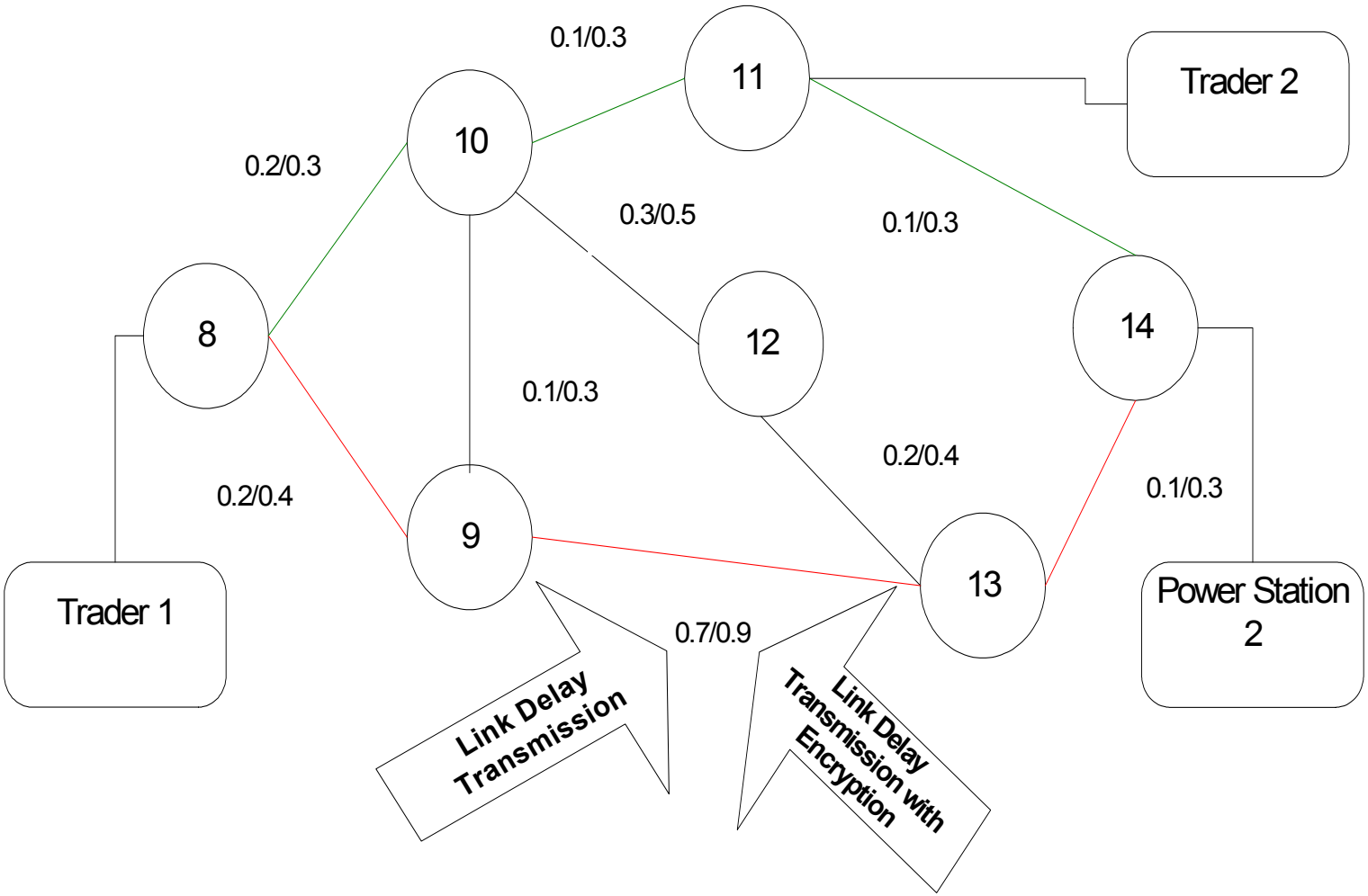
Point of view: Publish-Subscribe with Hierarchical QoS Managers



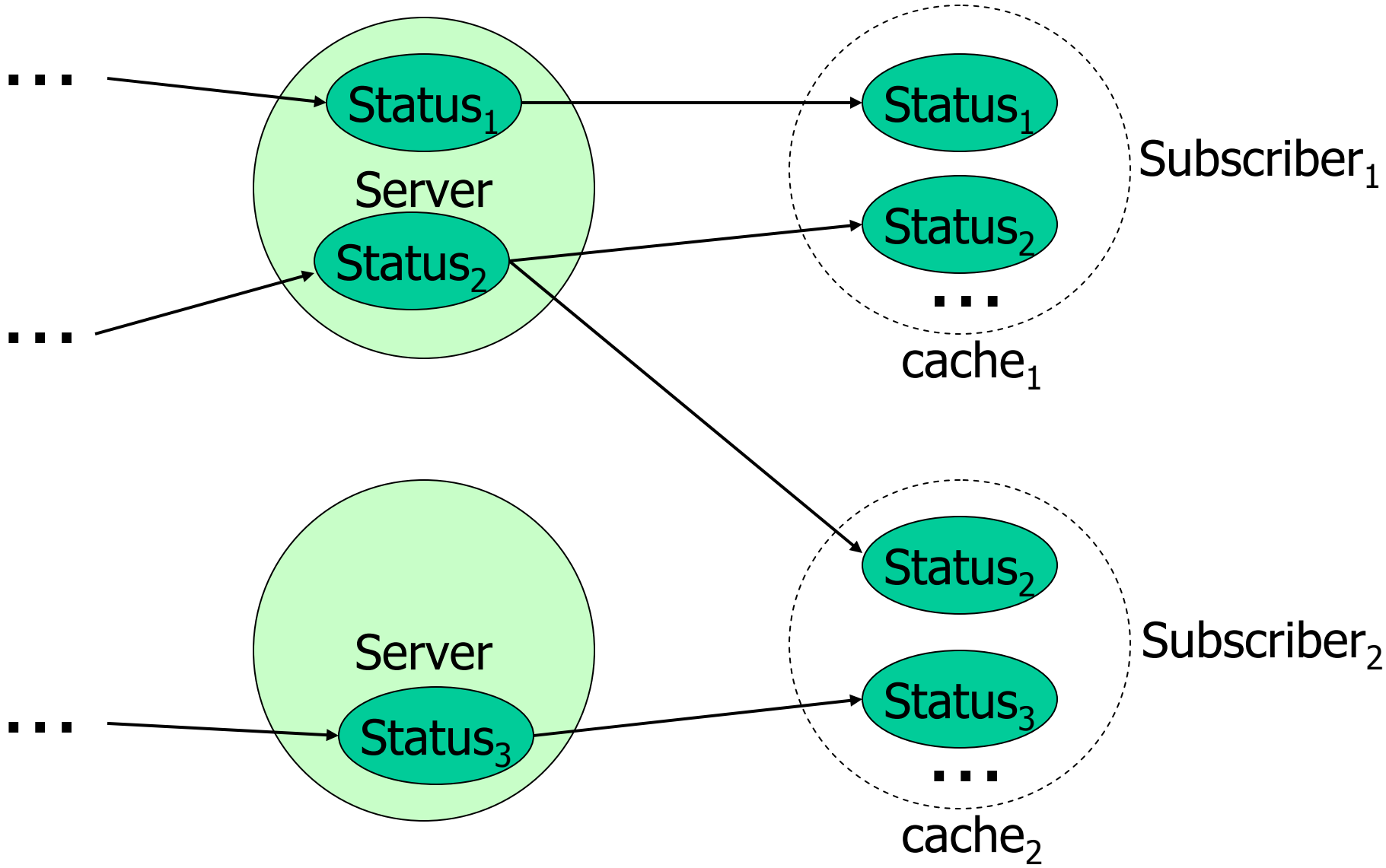
Point of view: Logical Publish-Subscribe



Sample Admission Control Graph



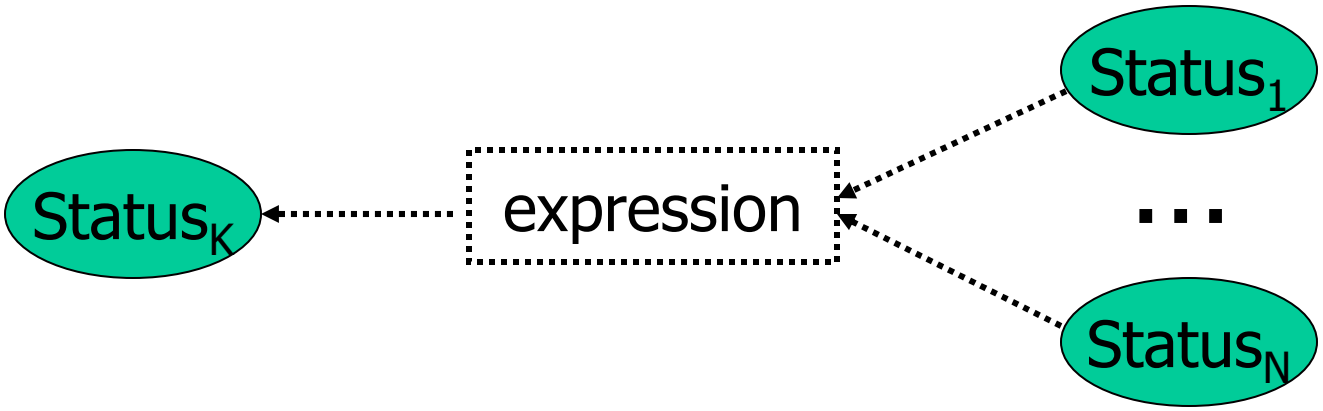
GridStat Subscribers Caches



Attributes of Status Items

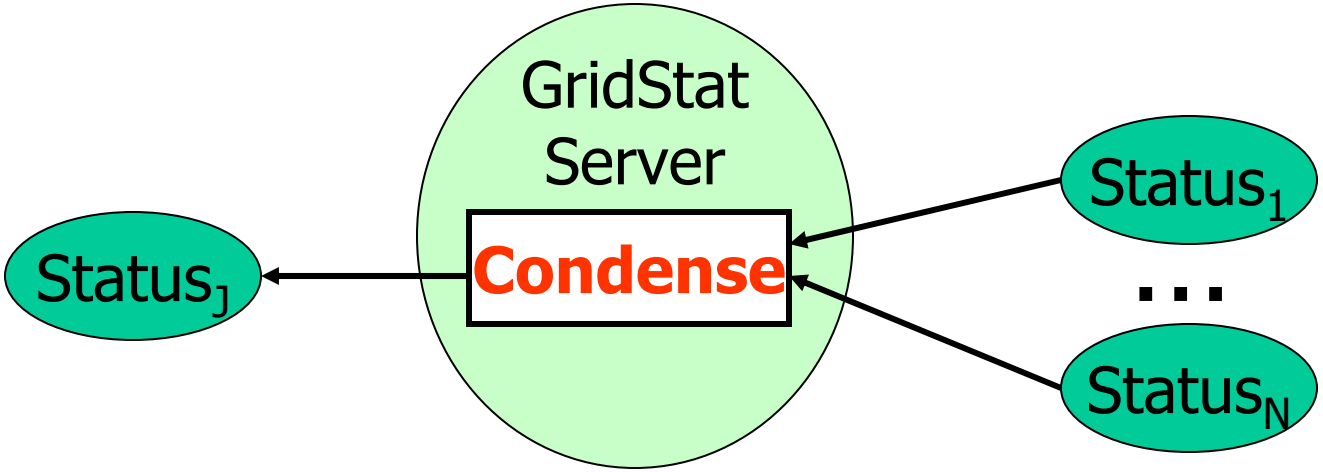
- A status item has the following attributes (initial set):
  - value (of type **bool** or **int** or **float**)
  - moving_average(t)
  - change_rate
  - change_rate_moving_average(t)
  - max(t), min(t)
- Static attributes
  - name
  - principal (user/owner) of publisher
  - …. probably more

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

Who sets what	Publisher	Subscriber	QoS manager
Redundancy (space)		√	√
Delivery rate		√	√
Delivery timeliness		√	√
Publisher rate	√		√
Priority	√	√	√
Confidentiality		√	√
Integrity		√	√
Access Control			√

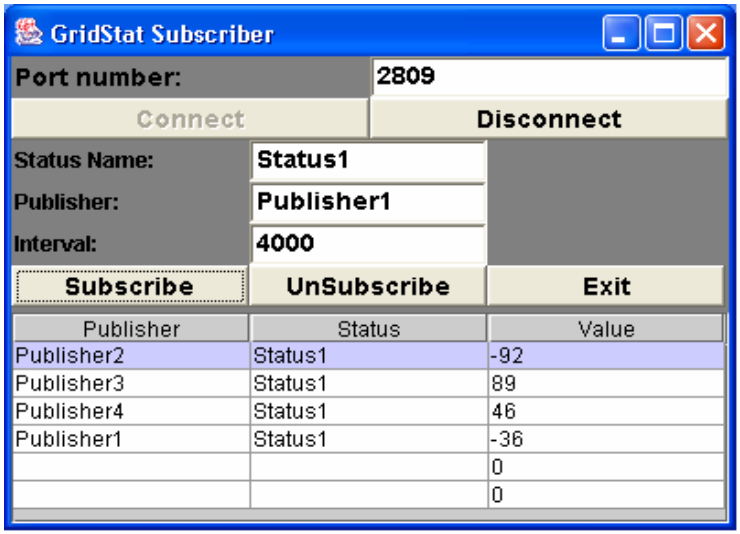
Note: QoS Manager can override Publishers and Subscribers specifications

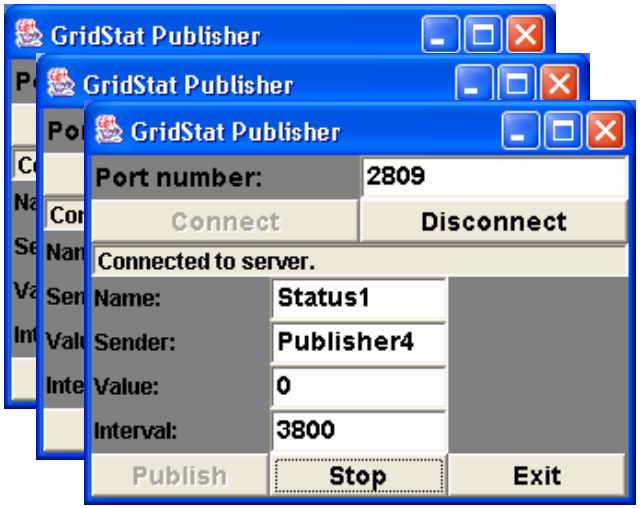
Related Work

- 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