Requirements & Mechanisms for Flexible and Robust Inter-Utility Data Sharing

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WASHINGTON STATE UNIVERSITY

http://gridstat.net

GridStat Team

- Faculty: Dave Bakken, Carl Hauser, Anjan Bose
- Current Students:
  - Graduate, Jim Kusznir, Sunil Muthuswamy, Erik Solum, Wendy Maiden (PNNL), Kim Swenson
  - Undergraduate: Loren Hoffman, Dave Anderson, Nathan Schubkegel
- Alumni:
  - Graduate students: Stian Abselsen (MS 2007), Erlend Viddal (MS 2007), Joel Hekley (MS 2007), Ioanna Dionysiou (PhD 2007), Kjell "Harald" Gjermundrød (PhD 2007), Venkata Irava (PhD 2007), Ryan Johnston (MS 2005), Ping Jiang (MS 2004), Suprith Sheshadri (MS 2005)
  - Undergraduates: about a dozen on senior projects (Avista)
- Note: all above students are computer science
  - Also working w/Sudipto Bhowmik (PhD EE soon, almost MS CS)

Main Points

- You have an IT problem, not a power problem
- Move past interim solutions (think outside the box): TCP, concentrators, hard-coded, point-to-point, unmanaged, single point of failure & congestion
- Move towards flexible, robust/redundant, peer-to-peer & mesh, managed, data delivery services (NOT “web services”)
  - These data delivery services must be provided ABOVE the “network level” (TCP, ethernet, etc)

Outline of Seminar

- **The (IT) Problem**
- Requirements for Inter-Utility Data Delivery Services
- Distributed Computing Technologies
- GridStat Data Delivery Framework

IT Problem Space

- US Electric Power Communications System is aging
  - SCADA & ICMP are 1960s technology
  - Not updated meaningfully (no industry investment)
  - Much star-connected, inflexible, slow, crude SCADA "polling"
  - **Very little between electric utilities overall**
- Data collection has increased many fold at substations
  - Faster measurement rates, often time synchronized
  - Communications not there to move this data where needed

Consequences of Limited Data Exchange

- Much less visibility into system
- Greatly limits control opportunities
- Greatly limits protection opportunities
  - SPS/RAS are too expensive, one-off solutions
- Limits reliability: major blackout contributor
- Limits profits (!!)
  - Monitoring systems that can run the system at higher load levels (and of course hence with more profitably) are one of the "exciting new technologies that will be tools for the future".

    Root, C. "The Future Beckons", *IEEE Power & Energy Magazine*, 4(1), January/February 2006, 24–31.

IT Problem Space (2)

- Francis Cleveland, Xanthus consulting (**emphasis** ours)
  - *With the exception of the initial power equipment problems in the August 14, 2003 blackout, the on-going and cascading failures were **almost exclusively due to problems in providing the right information to the right place within the right time**.*
- Clark Gellings, EPRI (**emphasis** ours)
  - *"The **ultimate challenge** in creating the power delivery system of the 21st century is in the development of **a communications infrastructure that allows for universal connectivity**."*
  - *"In order to create this new power delivery system, what is needed is a **national electricity-communications superhighway** that links generation, transmission, substations, consumers, and distribution and delivery controllers."*

IT Problem Space (3)

- Ultimate solution by vendors?? … need to work with IT vendors, not traditional control center vendors for this
  - You cannot buy COTS data delivery services today for wide-area that come even close to what is needed
- Difference between network and distributed computing
  - Network: get bytes from point A to point B, with some A-B rate and latency
  - Distributed Computing: embodied knowledge of *how* to use a network to make data delivery (and other services) more reliable, timely, etc. at an application (not byte) level
- Note: distributed computing "middleware" widely used for 10+ years in aerospace, trains, military, other industries
- Need interoperability/standardization across utilities

Present Interim Solutions

- Need to move past interim solutions (think outside the box):
  - TCP: not meant for predictable latency
  - Concentrators/databases in critical path of data delivery service
    - Slow down the time critical data delivery
    - single point of failure & congestion
  - hard-coded, point-to-point
  - Unmanaged (over-provisioning is insufficient and expensive!)
  - IPV6
  - Bridged ethernet

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Requirements in Detail

Kinds of Requirements:

1. Quality of Service (QoS) …
2. Flexibility …
3. Other …

Given now in detail, see our Tech Report 009 (citation at end) for many citations to industry standards and sources

QoS Requirements

- Latency
  - 4 ms within substation, 8-12 external for all but very fastest
- Availability of Data: if applications are important, so are their input data (and output decisions/analysis)!
  - Levels from Medium (99.0%) to Ultra (99.9999%)

Flexibility Requirements

- Multicast
- Heterogeneity of communication topologies
- Heterogeneity of delivery latency and delivery rate
- Temporal synchronism
- Heterogeneity of computing resources
- Extensibility to new kinds of computing resources
- Open architecture: easy interoperability across multiple vendors

Tomorrow's applications need this flexibility, too: smart grids, advanced metering infrastructure (enabling demand response), …

Other Requirements

Mostly cyber security…

- Confidentiality
- Integrity
- Availability

But traditional cyber-security is not enough

- **Trust management**: systematically reasoning about
  - How much trust to place in data received, especially when via
    - Chains of processing (pub-sub)
    - Aggregation of many different inputs from different sources
  - How much access to data to provide potentially untrustworthy entities

Outline of Seminar

- The (IT) Problem
- Requirements for Inter-Utility Data Delivery Services
- **Distributed Computing Technologies**
- GridStat Data Delivery Framework

Distributed Computing 101

- Difference between network and distributed computing
  - Network: get bytes from point A to point B, with some A-B rate and latency
  - Distributed Computing: embodied knowledge of *how* to use a network to make data delivery (and other services) more reliable, timely, etc. at an application (not byte) level
- Note: distributed computing "middleware" widely used for 10+ years in aerospace, trains, military, other industries
  - Power engineers (and many IT personnell) unaware of many advances in last few decades
- Don't use "Web services" for real-time data delivery…
- Don't use TCP (i.e., TCP/IP) for real-time data delivery…
- Lots more details in our report (TR 009) at end…

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- Distributed Computing Technologies
- **GridStat Data Delivery Framework**

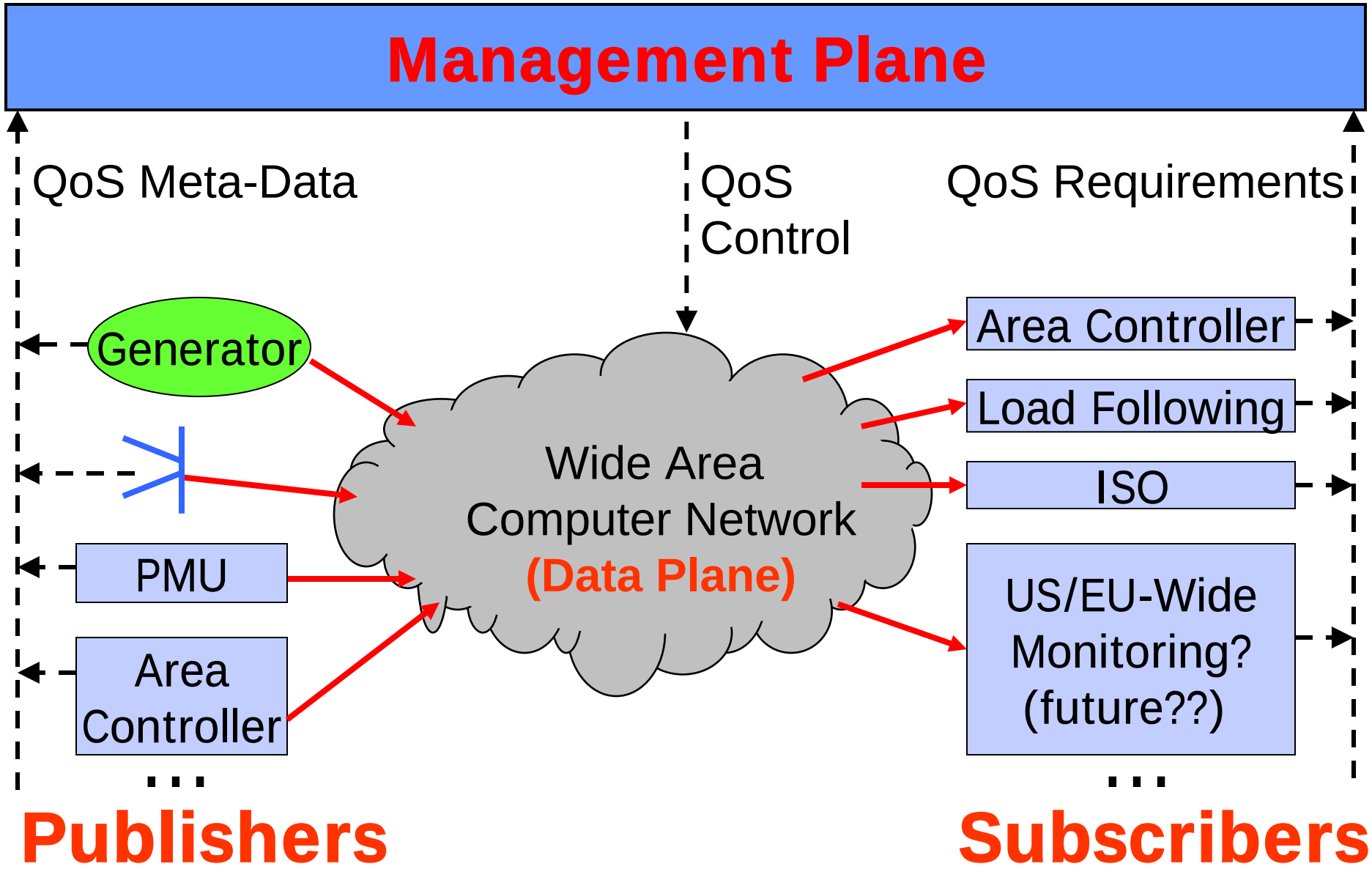
GridStat in a Nutshell

- Next-generation communications infrastructure for the electric power grid
  - Researching since 1999, first demo in 2002, Avista tech. demo
  - Pilot project starting INL-PNNL (and others)
- Provides flexible delivery of status data, including PMUs
- "Status Routers" forward status updates and alerts with quality of service mechanisms (rate filtering, multicast)
  - SW latency ~0.5ms (Java) and 50K/sec
  - Network processor version (ongoing) much, much better
- Managed infrastructure allowing for changing status delivery and adding new subscribers with software
  - Manages multiple redundant paths for fault-tolerance
- Deployable on top of IP, ATM, network processors, …

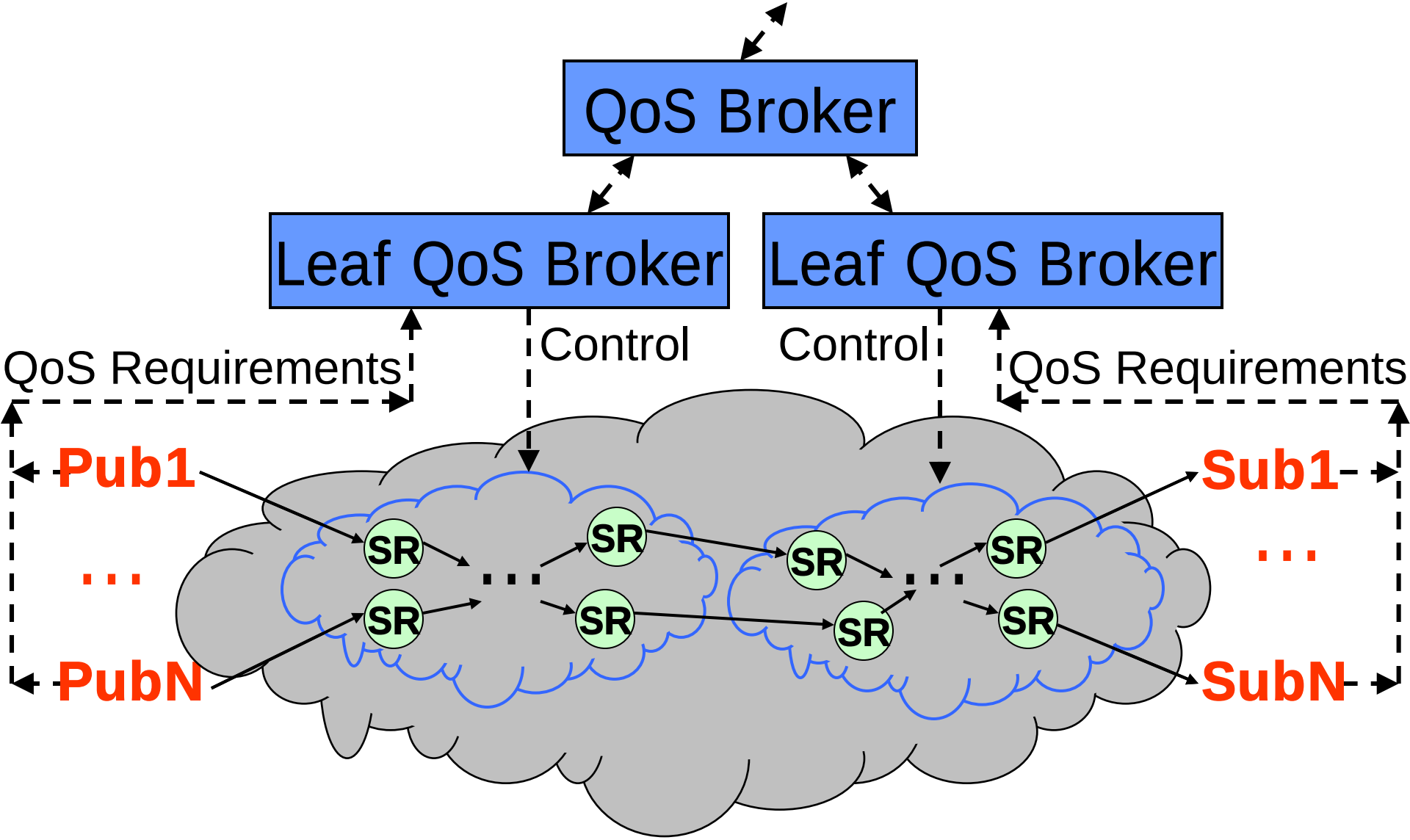
GridStat is Publish-Subscribe Middleware

- Publisher: periodically announce status values
- Subscriber: periodically receive status values
- Simple middleware APIs (CORBA, .NET) for both publishers and subscribers, management/control infrastructure, etc.
- Network of internal status routers (SRs) managed for QoS – timeliness, redundancy and security
  - Middleware-level store-and-forward with rate filtering & multicast
  - Data plane kept separate from management plane
- Optimized for semantics of status items
  - Not just arbitrary event delivery like generic publish-subscribe
  - Different subscribers (subtrees) can get different rates
  - Designed to allow many adaptations (global, regional, local) assuming semantics of status updates

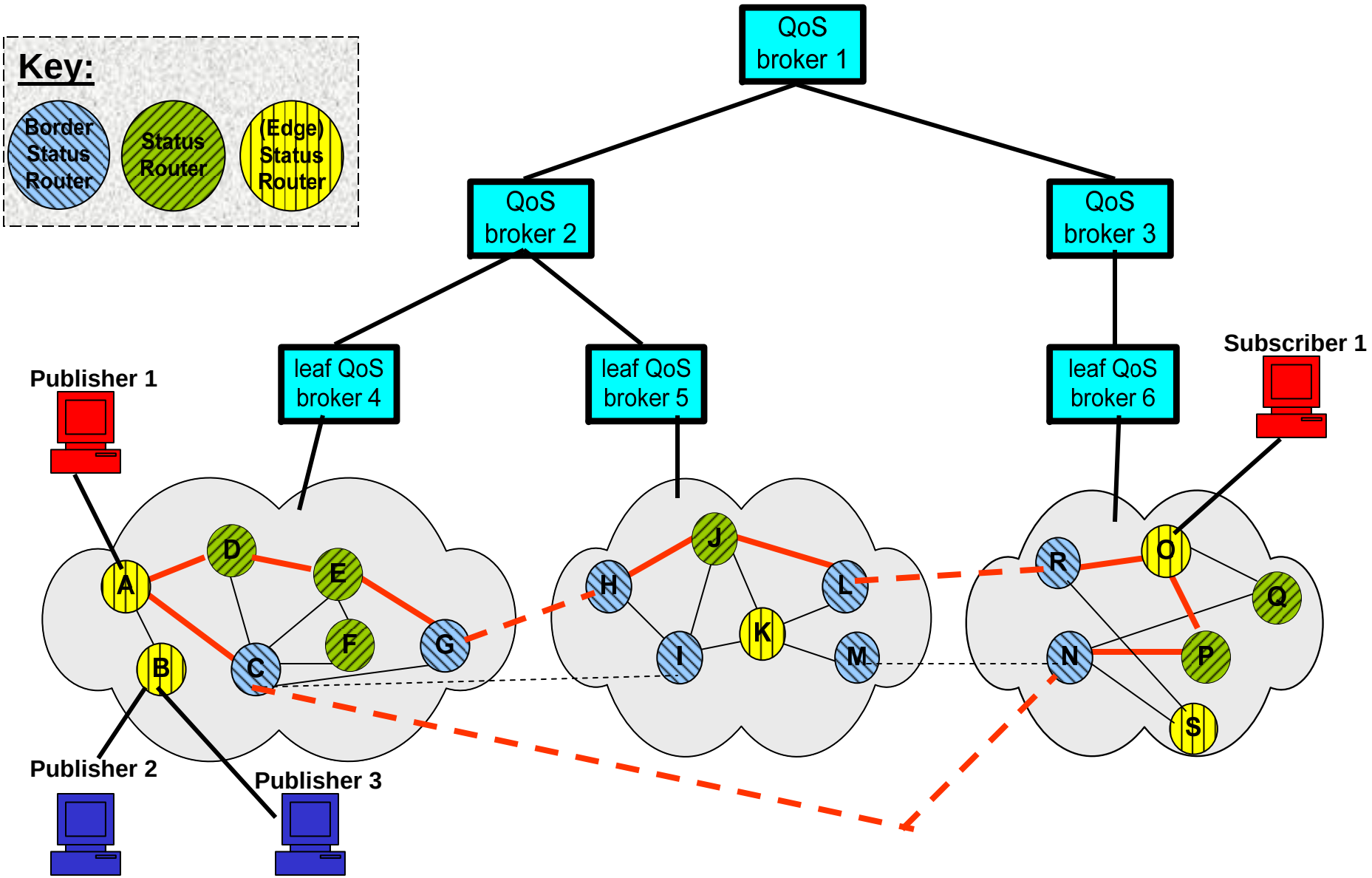
Basic GridStat Functionality



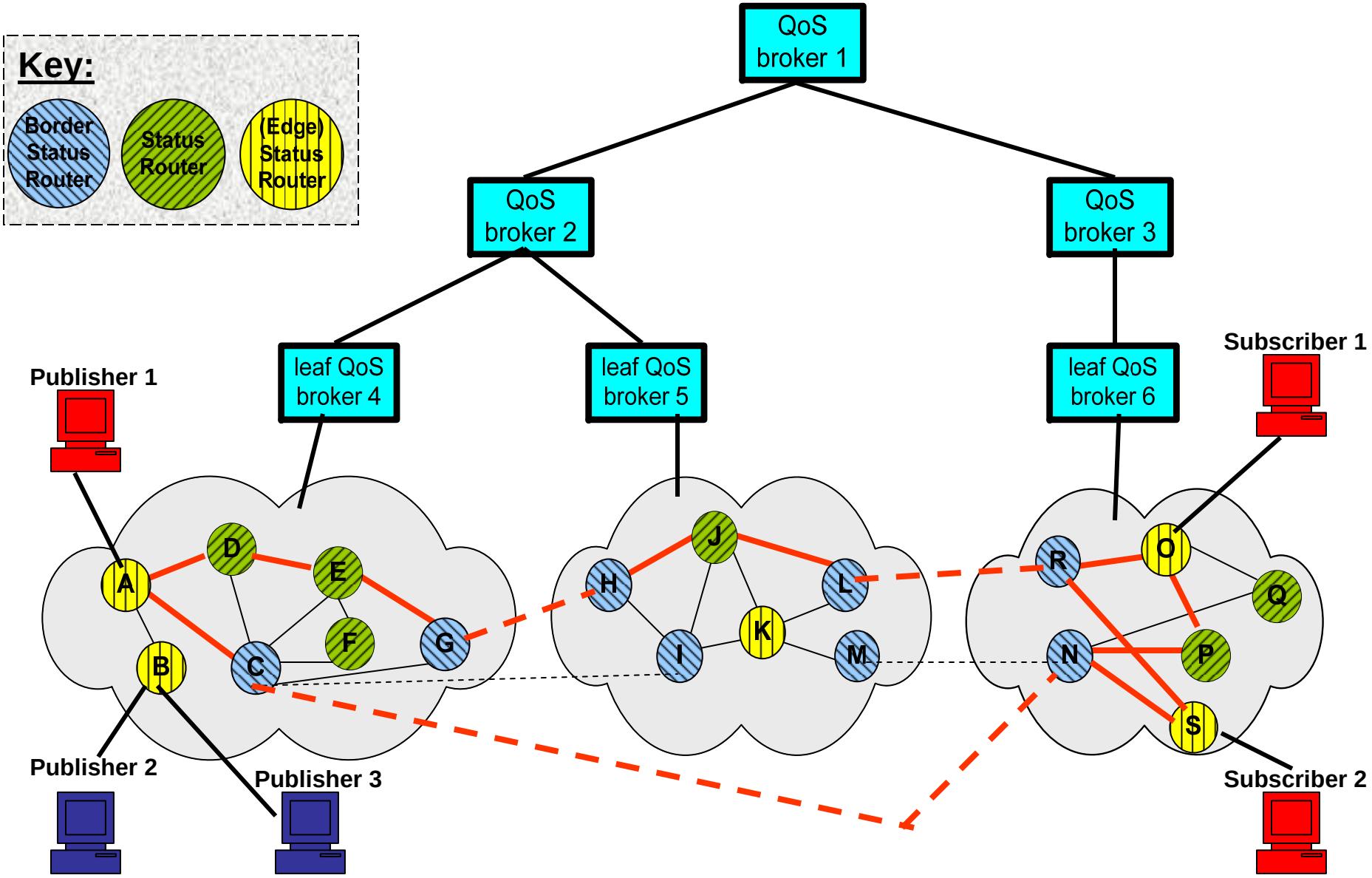
GridStat Architecture



Route Allocation to Subscriber 1



Route Allocation to Subscriber 2



Note: Sub2 may have a different rate, latency, or redundancy than Sub1

Conclusions

- Limited inter-utility data exchange greatly limits situation awareness, control, protection, reliability, and profits of grid
- Distributed computing technologies can help provide the needed flexibility, robustness
- GridStat data delivery framework provides data delivery
  - Managed mesh network
  - QoS management (latency, rate, redundant paths)

For More Info

- www.gridstat.net
- http://www.iti.uiuc.edu/tcip/index.html
  - TCIP cyber-security center funded by NSF, DoE, DHS
- See papers:

"A Failure to Communicate: Next-Generation Communication Requirements, Technologies, and Architecture for the Electric Power Grid", *IEEE Power & Energy Magazine*, March/April 2005,47-55. www.gridstat.net/intro.pdf

David E. Bakken, Carl H. Hauser, Harald Gjermundrød, and Anjan Bose. "Towards More Flexible and Robust Data Delivery for Monitoring and Control of the Electric Power Grid", *Technical Report EECS-GS-009*, School of Electrical Engineering and Computer Science, Washington State University, May 30, 2007. Available via http://www.gridstat.net/TR-GS-009.pdf