

Goals

- Provide a Cooperative Congestion Control framework to be used in the NASPInet.
- Protect the real-time guarantees of PMU flows during transient instability periods.
- Utilize the cooperative nature of the nodes in the NASPInet and the flows that originate from the same substation.

Fundamental Questions/Challenges

- Real-time guarantees (end-end latency deadlines and critical data loss rate) of PMU flows can be violated when transient congestion occurs in the NASPInet.
- Congestion of traffic in the power grid communication network (NASPInet) can be caused by:
 - Variable compression of the PMU data or other sensory data.
 - Increased sending rate of real-time (RT) PMU flows due to unexpected critical event/observation in their sensory space.
 - Changing demands by control centers due to extended power grid state analysis, causing changes in traffic shapes of RT flows.
- Need for an approach that can control congestion with the cooperation of the nodes in the network and the cooperative flows from the same substation.

Research Plan

- Cooperative Congestion Control (CCC) Framework
 - Multiple service class queuing.
 - Cooperative real-time flow scheduling and BW reassignment.
 - Cooperative coordination and back pressure approaches among neighboring nodes to counter the transient congestion state.
- CCC framework includes:
 - Overlay Router/Phasor Gateway design.
 - Congestion Notification Protocol.

Controller Component

- Creates other components.
- Maintains metadata and reservation of flows, including the correlation and priority info.

Data Connections Component

- Handles pub-sub data flow connections at the overlay router.

Adapter Component

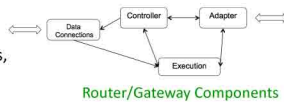
- BW reassignment algorithm and cooperative coordination protocol reside here.
- Maintain the link sharing queue hierarchy and update statistics periodically.
- Adapt to any transient congestion occurrence by BW reassignment.
- Communicate with the adapters of neighboring nodes, notifying them about new rate (BW) assignments.

BW Reassignment Algorithm:

- The algorithm selects a list of victim Low Real Time (LRT) & Best Effort (BE) flows for each congested High Real Time (HRT) flow i .
- The list is selected based on the priority of flows and the correlation among the flows.

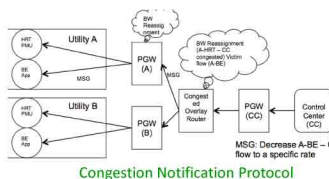
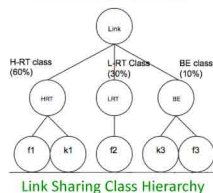
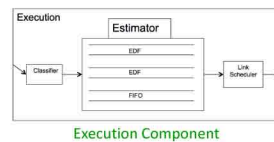
Congestion Notification Protocol:

- Informs the cooperative neighboring adapters about the changed BW shares of flows.
- Internal network nodes perform BW reassignment and inform upstream neighbors of it until the senders receive the new rates.

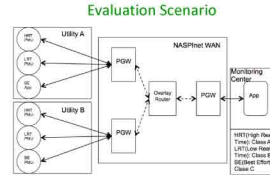


Execution Component

- Implements the real-time flow scheduling algorithms and multiple service class-based queuing.



Research Results



Flow	0 - 40	40 - 60	60 - 80	80 - 90	90 - 100
A-HRT	0%,0%	50%,4%	50%,0%	40%,1.8%	33%,0%
A-LRT	0%,0%	0%,0%	0%,0%	0%,1%	0%,0%
B-HRT	0%,0%	0%,0%	50%,3%	40%,1%	33%,0%
B-LRT	0%,0%	0%,0%	0%,0%	0%,1%	0%,0%

% of deadline missed packets (flow vs. time interval in sec) without and with CCC framework

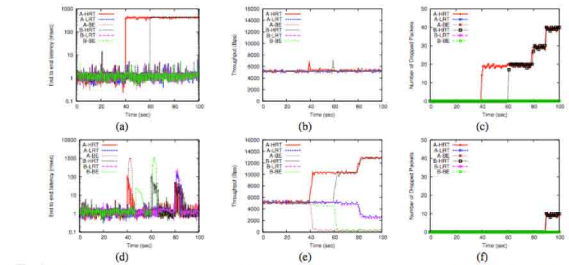


Fig. 9: Implementation, 11-node tested: Without CCC framework (a) End to end latency, (b) Throughput, (c) Buffer Overflow dropped packets. With CCC framework (d) End to end latency, (e) Throughput, (f) Buffer Overflow dropped packets

Our CCC framework made it possible to achieve real-time guarantees of the PMU flows during the transient instability period (between 40th and 100th sec).

Broader Impact

- Provision of stability of real-time streaming protocols in NASPInet framework.
- Exploration of transient failures and handling in SCADA networks under real-time requirements.

Interaction with Other Projects

- GridStat (WSU)

GridStat manages the pub-sub system with the domain-specific brokers in the management plane, performing a) admission control, b) registration, c) path setup and reservations, d) routing table setup, and e) recalculation of the path on events like congestion, change in requirements, etc.

- We extend GridStat with the CCC component to protect the real-time guarantees of PMU flows during transient instability periods.

Future Efforts

- Deploy the CCC framework along with other components in the NASPInet.
- Test it vigorously under different stress scenarios.

