



TCIPG

Trustworthy Cyber Infrastructure for the Power Grid

Cooperative Congestion Control in Power Grid Communication Networks

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Overview and Problem Statement

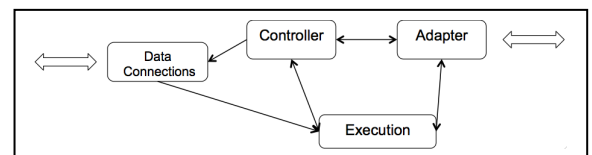
- Real-time guarantees (end-end latency deadlines and critical data loss rate) of PMU flows can be violated when transient congestion occurs in the NASPInet.
- Congestion of traffic in the power grid communication network (NASPInet) can be caused by:
 - Variable compression of the PMU data or other sensory data.
 - Increased sending rate of real-time (RT) PMU flows due to unexpected critical events/observations in their sensory space.
 - Changing demands by control centers due to extended power grid state analysis, causing changes in traffic shapes of RT flows.

Research Objectives

- Provide a Cooperative Congestion Control framework to be used in the NASPInet.
- Protect the real-time guarantees of the 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.
- **Smart Grid Application Area:** Wide Area Monitoring and Control

Technical Description and Solution Approach

- Cooperative Congestion Control (CCC) Framework
 - Multiple service class queuing,
 - Cooperative real-time flow scheduling and BW reassignment, and
 - 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

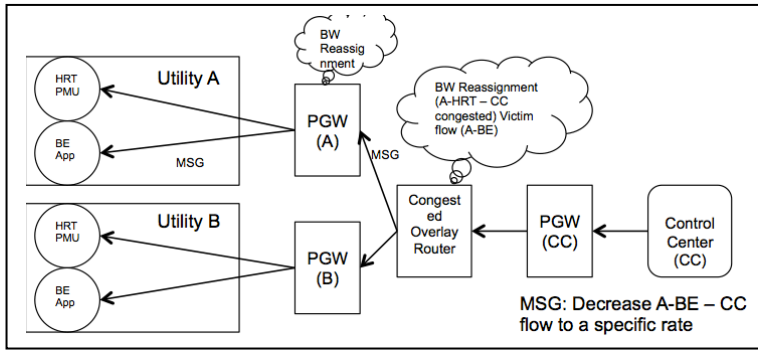


Router Components

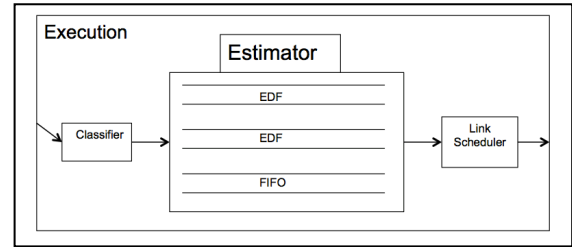
Adapter unit:

The adapter is the primary component where the BW reassignment algorithm and cooperative coordination protocol reside. Its main responsibilities include:

- a. Maintaining the link sharing queue hierarchy and updating statistics periodically,
- b. Adapting to any transient congestion occurrence by bandwidth reassignment, and
- c. Communicating with the adapters of neighboring nodes, notifying them about the new rate (BW) assignments.



Congestion Notification Protocol

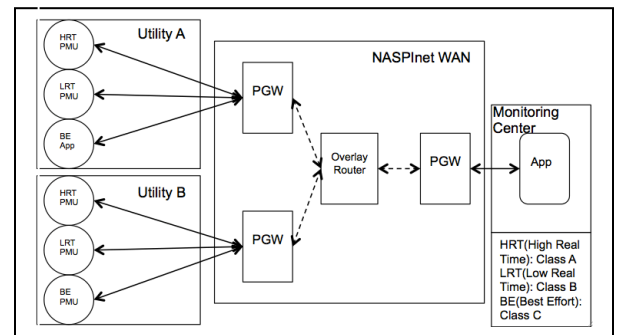


Execution Component

Results and Benefits

- **Technology Readiness Level:** Modules available for deployment

- At $t = 0$, all flows start with an initial frequency of 20 Hz.
- At $t = 40$ sec, the Utility A's HRT PMU sensor increases its frequency to 40 Hz.
- Later, at $t = 60$ sec, Utility B's HRT PMU sensor increases its frequency to 40 Hz.
- At $t = 80$ sec, Utility A's HRT PMU and Utility B's HRT PMU increase their frequencies to 50 Hz.
- Finally, at $t = 90$ sec, Utility A's HRT PMU and B-HRT PMU increase their frequencies to 60 Hz.



Evaluation Scenario

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

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).

Researchers

- Naveen Cherukuri, naveen.cherukuri@oracle.com
- Klara Nahrstedt, klara@cs.illinois.edu