2022 NSF CYBER-PHYSICAL SYSTEMS PRINCIPAL INVESTIGATORS' MEETING

Coupled Cascading Failure in Energy CPS: Modeling, Prevention, and Restoration

Nilanjan Ray Chaudhuri, PI, Associate Professor, Ting He, Co-PI, Associate Professor, Thomas La Porta, Co-PI, Professor
Sina Gharebaghi, Graduate RA, Yudi Huang, Graduate RA, Vajiheh Farhadi, Graduate RA
The Pennsylvania State University

Award ID # ECCS1836827

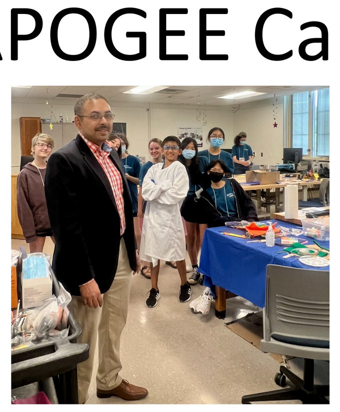
Challenge:

- **Modeling**:
  - Dynamic models are accurate, but statistical analysis impossible due to computational burden
- **Prevention**:
  - Mitigating cascade by generation rescheduling considering stability limits and uncertainty in controllability and observability
  - Preventing outages due to cyber-physical attacks via secured PMU
- **Recovery**:
  - Resolving uncertainty about failure locations due to lack of information from sensors

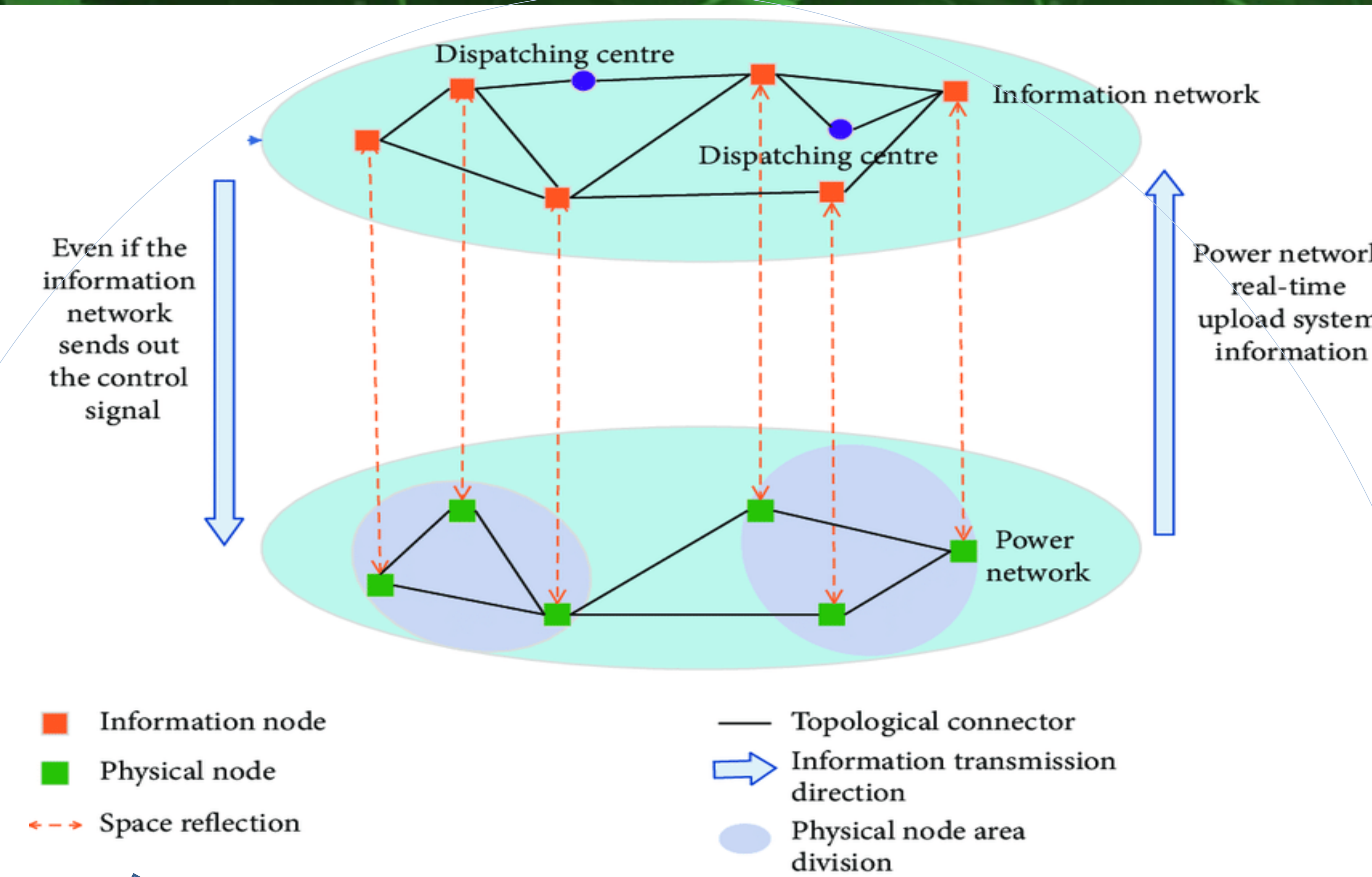
Broader Impact: Preventing cascading failures in the electrical energy CPS can save a significant number of customer-hours of lost electricity service, billions of dollars of loss in economy.

Outreach:

APOGEE Camp

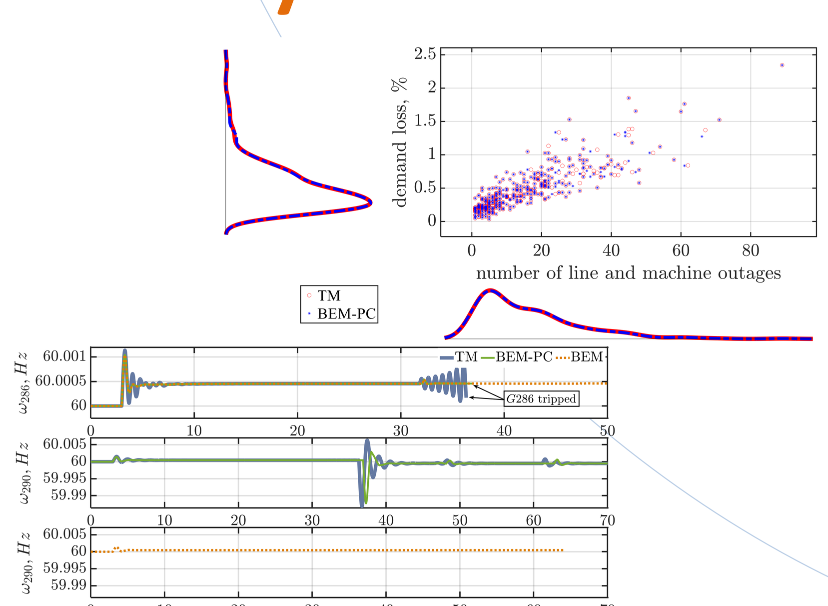


CSE Girl's Camp

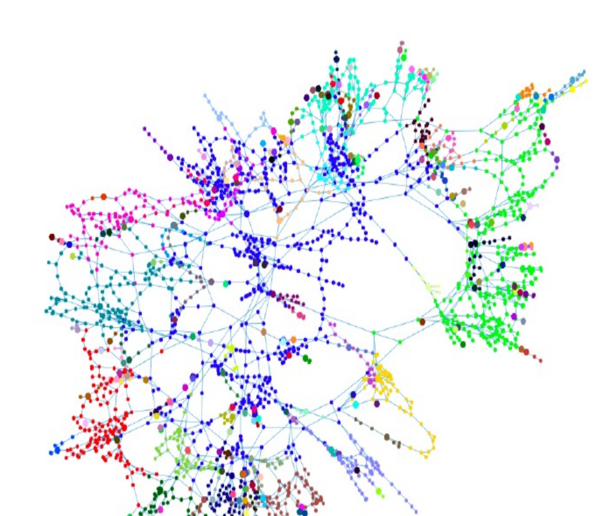


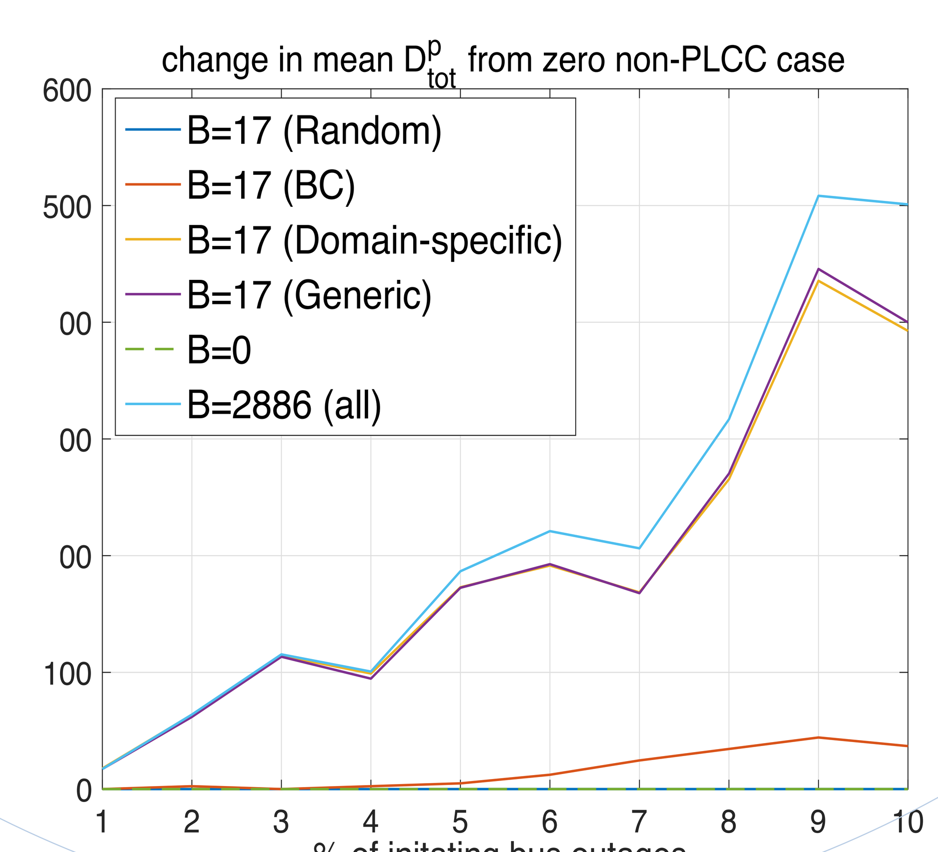
Modeling

- 35x avg. speedup in 2300 bus grid
- Provisional Patent filed by PSU

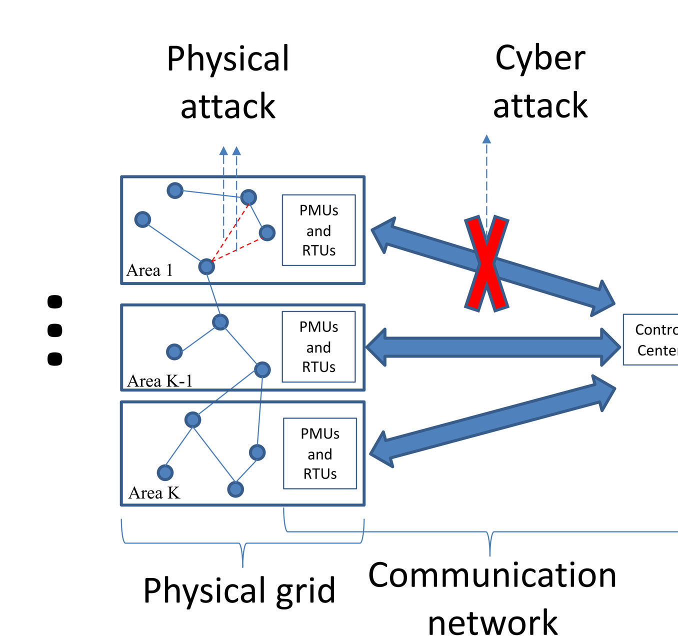


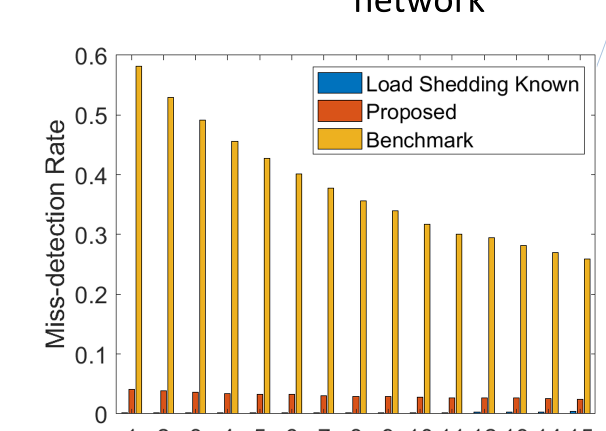
Prevention

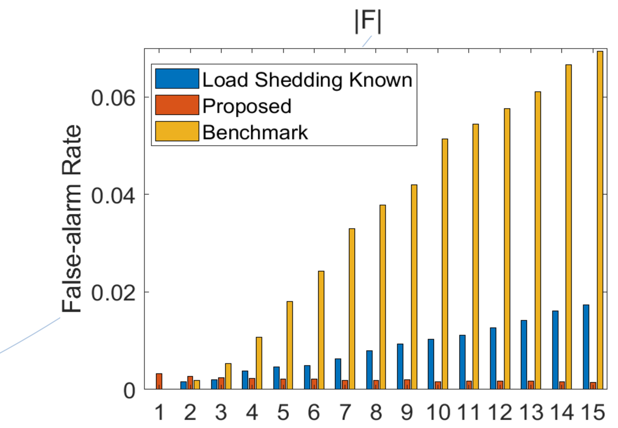




Restoration







Solution:

- **Modeling**: A new approach for fast cascading failure simulation in dynamic models of power systems – Backward-Euler method with predictor-corrector (BEM-PC)
  - Average 35x speedup in 2383 bus Polish System
- **Prevention**: Allocating preventive resources to mitigate impact
  - placing limited non-PLCC links to maximize load served after failure
  - placing fewest secured PMUs to prevent outages under CCPA
- **Recovery**: LP-based failure localization algorithm with verifiable correctness under islanding

Scientific Impact:

- **Modeling**: CPSs with complex dynamic models of the physical layer can use BEM-PC
- **Prevention**: Economic allocation of resources (non-PLCC links, secured PMUs) to maximize observability and minimize lost service
- **Recovery**: Estimating unobservable state variables and topology under islanding