

# **NSF 0931978: A Computing Framework for Distributed Decision Making to Ensure Robustness of Complex Man-Made Network Systems: The Case of the Electric Power Networks**

**Principal Investigators:** Rohit Negi, Marija Ilic, Franz Franchetti, Ole Mengshoel • Carnegie Mellon University

This project aims to develop methods to monitor and ensure the robustness of the Electric Power Network (EPN), which is arguably the largest cyber-physical system in operation today, comprising 300,000 km of high voltage lines, 15000 generators and 5000 distribution facilities in the US. The EPN is an example of a special type of cyber-physical system, that we can call a Physical Network (PhyNet), since its basic behavior is defined by well-known physical laws. While the EPN is vital for economics and national security, it is subject to a dangerous lack of robustness, resulting in large scale ‘black-outs’. Further, the SCADA system that controls the grid needs to adapt to projected future changes in the EPN, such as the introduction of new types of meters (PMUs), distributed and variable generation sources such as wind, and distribution level fine-grained control through the smart grid. Our multi-disciplinary team of PIs, which covers the areas of electric power networks, network theory, machine learning and high performance computing, is well-suited to address these problems of the EPN. The solutions to these problems will illustrate how *a large and complex cyber-physical system, which is based on physical laws (PhyNet), can be monitored and controlled*, given adequate computing resources.

The EPN must be robust to various disturbances, which requires suitable *control* algorithms. Such algorithms must be aware of the system state, so that *estimation* methods are required for EPN. Both control and estimation will work well if there are suitable *models* of the EPN, perhaps obtained by data driven machine learning. All these algorithms require intensive computation on large networks, which must be supported by high performance *computing* research. This poster will present examples of each of these activities. For control, we are investigating the problem of Automatic Generation control, which decomposes the control area into several interacting control areas. We are also studying scheduling strategies for the future smart grid, which can reduce peak system load, and thus, make the system robust to disturbances. For state estimation, we are investigating novel algorithms that are robust to outliers, and account for non-linearities in the system model. Data driven learning to predict faults in a graphical model of a vehicular electric network is being studied, to understand how complex system behavior can be modeled and predicted by state of the art machine learning. High performance computing implementations of certain core algorithms in EPN are being investigated, such as Monte Carlo calculations of optimal power flow in the distribution sub-network of EPN.