Background
Daily societal activities increasingly depend on interdependent critical infrastructures such as power grids, telecommunication networks, transportation networks, food networks, and water distribution networks. In contrast to isolated systems, interdependent networked systems demonstrate emergent behaviors caused by unpredictable, rare, nonlinear interactions between numerous social, physical, and cyber components. Because infrastructure systems are large, they are often decentrally controlled through cyber systems. Although decentralization and self-organization theoretically reduce failure risk, interdependencies can lead to disruptive and massive cascading failures.

Interdependent and multilayer networks characterize critical social and engineered infrastructures, but a thorough understanding of their behaviors through fundamental results is still lacking. For example, the Smart Grid concept includes application of advanced computer, communications, and power technologies to obtain a highly automated, responsive, and resilient, transmission and distribution infrastructure. At the distribution level, the Smart Grid integrates distributed renewable generation sources with energy storage and provides demand response management to customers through dynamic pricing. At the transmission level, communication architecture creates an intelligent infrastructure that can detect and mitigate faults faster than those faults can propagate, thus providing utility operators with improved efficiency and reliability. Although ongoing efforts to design a next-generation communication network within the Smart Grid framework are in progress, lack of flexibility and programmability of network equipment has impeded experimentation of new schemes. Consequently, power operators are reluctant to adopt untested solutions.

Description
This project has two primary goals. The first goal is to study interdependencies between critical infrastructure networks and provide fundamental insights on the impact of these interdependencies related to reliability of the coupled system in order to increase reliability by developing analytical tools to measure and adapt system interdependencies. The second goal is to address key issues in order to allow rigorous experimentation and analysis of networking solutions in the real-world environment. For example, large-scale experiments that incorporate resources from the Smart Grid Lab at Kansas State University (KSU), KSU networking resources, and the Global Environment for Network Innovations (GENI) test bed will be performed.

To date, a hybrid simulator has been created that integrates continuous-time behaviors of the power system with discrete event behaviors of the communication network. This platform has demonstrated performance impacts of the communication network and the power system when the physical infrastructure is designed to maximize robustness. Furthermore, this platform demonstrated that an OpenFlow communication network could perform equally well to or better than its Multiprotocol Label Switching (MPLS) counterpart. Finally, a Smart Grid prototype was deployed on the nationwide GENI network test bed to demonstrate OpenFlow’s ability to provide services comparable to MPLS.

Relevance
Numerous critical infrastructures in Kansas and the United States rely on secure networking and communications. In Kansas, power and networking companies have demonstrated endorsement by sponsoring KSU’s Electrical Power Affiliate’s Program (EPAP). This research has also received national contributions from Raytheon BBN Technologies, KanREN, Internet2, the National Science Foundation, and National LambdaRail.

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Summary: This project will study interdependencies between critical infrastructure networks, providing fundamental insights regarding interdependency impacts on coupled system reliability in order to increase reliability by developing analytical tools to measure and adapt system interdependencies. This project will use rigorous experimentation and analysis of networking solutions in real-world environments.

Opportunity: Daily societal activities increasingly require interdependent critical infrastructures such as power grids, telecommunication networks, transportation networks, food networks, and water distribution networks. In contrast to isolated systems, interdependent networked systems demonstrate emergent behaviors caused by unpredictable, rare, nonlinear interactions between numerous social, physical, and cyber components. Because infrastructure systems are large, cyber systems often use decentralization to control those systems. However, even if decentralization and self-organization theoretically reduce failure risk, interdependencies can lead to disruptive and massive cascading failures. Interdependent and multilayer networks characterize many important social and engineered infrastructures, but a complete understanding of their behaviors using fundamental results is still lacking.

Solution: This project will investigate interdependent networks by studying the power grid and the communication network that form a Smart Grid. Researchers will perform large-scale experiments that incorporate resources from the Smart Grid Laboratory at Kansas State University and the Global Environment for Network Innovations (GENI) test bed. In addition, a hybrid simulator has been created that integrates continuous-time behaviors of the power system with discrete event behaviors of the communication network. This platform has demonstrated performance impact of the communication network and power system when the physical infrastructure is designed to maximize robustness.

Impact: Our group deployed a Smart Grid prototype on the GENI network test bed to demonstrate potential use of OpenFlow networking solutions.

Expertise: Network science and engineering.