The Vulnerability of Fiber Networks and Power Grids to Geographically Correlated Failures

Gil Zussman, Electrical Engineering, Columbia University (gil@ee.columbia.edu)[1]

Recent massive failures of the power grid (such as the Aug. 2003 blackout) demonstrated that large-scale and/or long-term failures will have devastating effects on almost every aspect in modern life, as well as on interdependent networks. In particular, telecommunications networks are vulnerable due to their strong dependence on power networks (e.g., the 2003 Italy blackout). Communication and power networks are vulnerable to natural disasters, such as earthquakes, floods, hurricane, and solar flare as well as to physical attacks, such as an electromagnetic pulse (EMP) attack. Such real world events happen in specific geographical locations and hence cause *geographically correlated failures*. Therefore, the geographical layout of the network determines the impact of such events.

This talk will focus on our recent results regarding the vulnerability of telecommunications networks and power grids to geographically correlated failure. We will present methods to identify the locations most vulnerable to large scale disasters. Our approach allows for identifying locations which require additional protection efforts (e.g., equipment shielding). Moreover, it may provide input to network and protocol design that could avert geographical disasters or attacks.

Particularly, in [3] we study the effect of geographically correlated failures in the context of fiber-optic networks. We consider a simplistic bipartite graph model and present a polynomial-time algorithm for finding a worst-case vertical line segment cut. We then generalize the network model to graphs with nodes at arbitrary locations. We model the disaster event as a line segment or a disk and develop polynomial-time algorithms that find a worst-case line segment cut and a worst-case circular cut.

In [1] we provide a unified framework to model the network vulnerability when the event has a probabilistic nature. Our framework captures scenarios with a number of simultaneous attacks, in which network components consist of several dependent subcomponents, and in which either a 1+1 or a 1:1 protection plan is in place. We use computational geometric tools to provide efficient algorithms to identify vulnerable points within the network under various metrics. In both [1, 3] we obtain numerical results for a specific backbone network, thereby demonstrating the applicability of our algorithms to real-world networks.

[1]Based on joint works with P. Agarwal, A. Bernstein, D. Bienstock, R. Cohen, A. Efrat, A. Ganjugunte, D. Hay, E. Modiano, S. Sankararaman, S. Neumayer, and M. Uzunoglu.

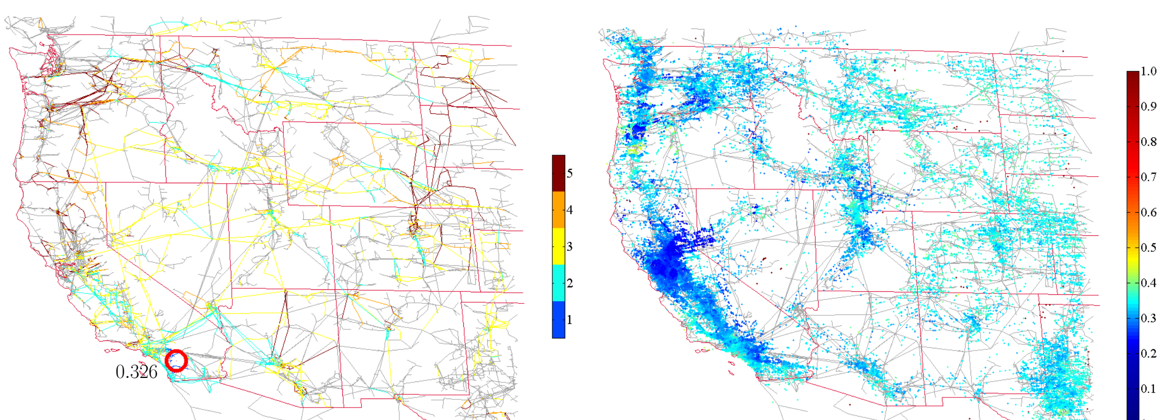

Figure 1: (left) 5 rounds of cascading failures initiated in south California (the colors represent the rounds in which the lines faulted); and (right) the yield values (at stability) of different failure locations (the color at each location represents the yield corresponding to an attack whose epicenter is at that location).

Finally, in [2] we consider power line outages that may have significant impact on the communication networks. In the transmission system, an outage of a line may lead to overload on other lines, thereby eventually leading to their outage. The effects of large scale geographically correlated outages differ from the effects of simultaneous outages that are spread throughout the grid. Hence, we show how to identify the most vulnerable locations in the grid and perform extensive numerical experiments with real grid data to investigate the various effects of geographically correlated outages and the resulting cascades. For example, Fig. 1 that was obtained using our method with real power grid data (albeit somewhat modified in order not to expose vulnerabilities) illustrates a cascade originating from a large attack in south California. The figure also shows the yield (ratio between the demand supplied following the cascade and the original demand) by attack location. These results provide insights into the relationships between various parameters and performance metrics, such as the size of the original event, the number of connected components, and the final yield.

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References

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