Estimating Directional Interdependencies Between Critical Infrastructure Networks Using GDELT Data

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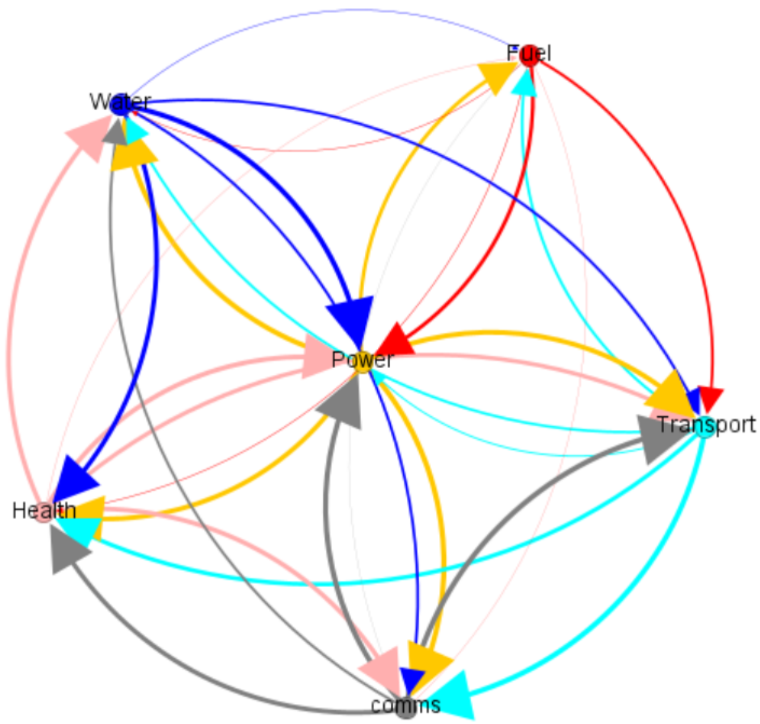

Understanding interdependencies between infrastructure networks has been a key focus area in understanding resilience and cascading failures. Specifically, an entire framework of interdependent networks has been developed and examples of interdependence between various infrastructures like power, transportation, communication, healthcare, water, and fuel and energy supply has been suggested.

Within the framework of interdependent networks, a key parameter has been the level of interdependence between particular infrastructure networks, often defined as q and representing what fraction of nodes in a particular network depend on nodes in another network (Parshani, Buldyrev, and Havlin, Physical Review Letters, 2010). Despite the importance of this parameter, for example in determining whether the network undergoes an abrupt or continuous transition, little effort has been made to estimate its value for particular pairs of interdependent infrastructure networks.

Here, using news data from the GDELT database we provide estimates of the level of interdependence between six key infrastructures: power, transportation, communication, healthcare, water, and fuel and energy supply. We do so by developing a list of keywords related to failures within each specificinfrastructure and gather articles mentioning these failures. We then identify in the articles where failures in multiple infrastructures are mentioned concurrently. This enables us to construct conditional probabilities that failures in one infrastructure lead to failures in another infrastructure offering an estimate of the level of interdependence between them. Furthermore, the conditional probabilities also offer unidirectional estimates of interdependence allowing us to disentangle potential differences between directional dependencies.

We find that the power network emerges as a key network that others networks tend to depend on much more, while of the power grid on other infrastructures appears more limited. Specifically, communication and water networks exhibit especially strong dependencies on both the power and transportation networks. Temporal analysis at a monthly resolution indicates that these dependency patterns remain stable throughout the year, showing no substantial seasonal variation.

This work and the associated values can further be used to refine estimates of q in models of interdependent networks offering real-world guidance on selection of a key parameter used in models of interdependent networks. Improvement of such models ultimately supports the construction of more resilient infrastructure systems.

Figure 1 illustrates the directional dependency network between the six infrastructure systems. Here, q_{ij} is empirically estimated from observed dependency intensities and captures the directional strength of coupling between infrastructure layers. This allows distinguishing asymmetric dependencies rather than assuming symmetric coupling.