AVALANCHE COLLAPSE OF INTERDEPENDENT NETWORKS

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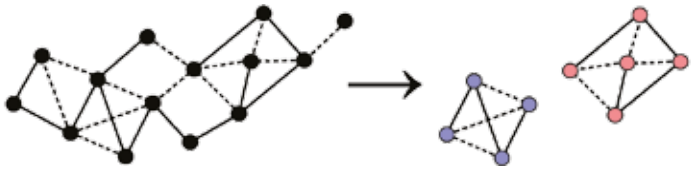

Many complex systems, both natural and man-made can be represented as interdependent networks, in which nodes in each network mutually depend on vertices in other networks, see Fig. 1. The interdependent networks demonstrate a rich set of features and effects unseen in ordinary single networks. Most impressive phenomena are related to avalanche collapse of the interdependent networks, in which an avalanche of damage spreads back and forth between the networks resulting in their complete disintegration. In particular, massive electrical blackouts and power outages, in which vitally interdependent power grids and controlling networks are involved, belong to this kind of phenomena.

In the simplest representative case, which we explore in detail, the interdependent networks can be reduced to the multiplex graphs, which have links of different kinds (coloured connections) and nodes of a single type. We study specific clusters within multiplex networks, in which between each two nodes, there exist paths of all possible colours (all links on a path should be of the same colour). These clusters are called viable clusters or viable components, see Fig. 2. We propose an algorithm enabling us to extract and index viable components in these networks.

We reveal the nature of the avalanche collapse of the giant viable component in multiplex networks under perturbations such as random damage. Specifically, we identify latent critical clusters associated with the avalanches of random damage. Divergence of their mean size signals the approach to the hybrid phase transition from one side, while there are no critical precursors on the other side. We find that this discontinuous transition occurs in scale-free multiplex networks whenever the mean degree of at least one of the interdependent networks does not diverge.

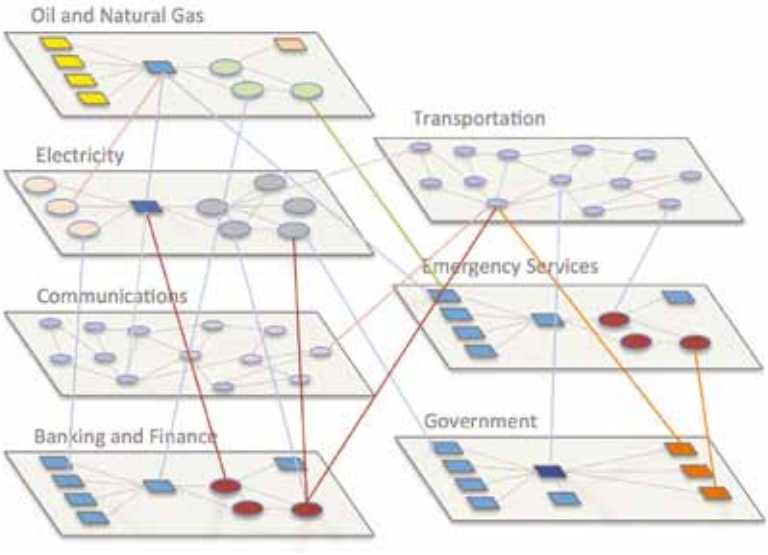

FIGURE 1
Organization of real-world interdependent networks. Various industrial, information, and other networks are actually interdependent. Interlinks between different layers show interdependencies.

FIGURE 2
A small multiplex network with two kinds of links. Applying the proposed algorithm non-viable vertices are removed leaving two viable clusters.