Attacks on modular networks

Saray Shai, Dror Y. Kenett, Yoed N. Kenett, Miriam Faust, Simon Dobson, and Shlomo Havlin

SUMMARY

Modularity is a key organization principle in many systems around us. Social, technological and biological systems are organized into cohesive groups of elements, called modules [1]. The relatively sparse interactions between the modules are critical to the functionality of the system, and are often the first to fail. Here we quantify the implications of such failures to the resilience of multi-scale modular systems. We find analytically a "tipping point", which distinct between two regimes. In one regime, the modules remain functional but become disconnected, while in the other regime the modules themselves are damaged causing the system to collapse.

ADDITIONAL DETAILS

We consider modular networks consisting of m modules (communities) and having a ratio of α between the probability for and intra-module and inter-module edge. Given α and m, along with the total average degree k, it is possible to compute the average inter-module degree, k_{inter} and the average intra-module degree k_{intra} and show that $\frac{k_{\text{intra}}}{k_{\text{inter}}} = \alpha/(m-1)$. Thus, our model considers systems comprised of more modules to have more inter-links. Using a multivariate generating functions approach [2], we find that for the case of random failure the critical occupation probability, p_c, and the giant component are no different from a regular (single module) network. However, for the case of an attack on the interconnected nodes, we find that for each α there exists a critical point, m^* below which the network first disintegrates into separate modules before being completely destroyed.

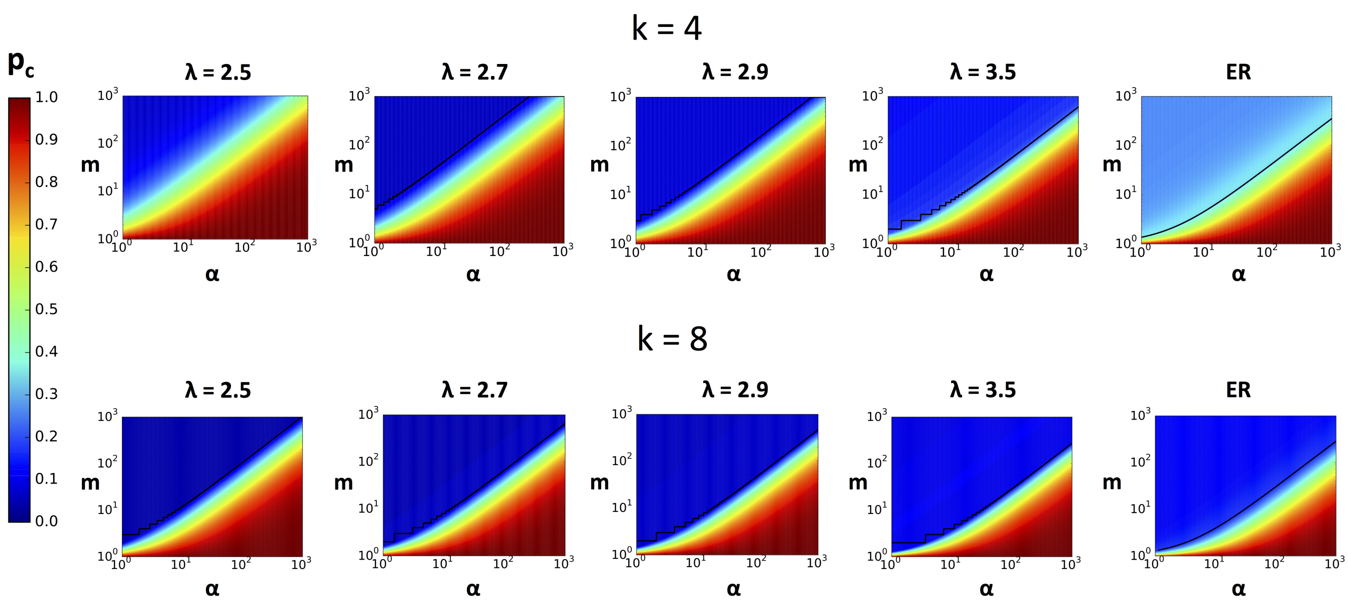

FIG. 1. **Tow parameter (α, m) phase diagram.** Analytical results for scale-free and random networks with mean degree k=4 (top) and k=8 (bottom). All diagrams were made using the same color bar. The black line corresponds to m^*.

[1] M. Girvan and M. E. J. Newman, Proc. Natl Acad. Sci. USA **99**, 7821 (2002).
[2] E. A. Leicht and R. M. D'Souza, (2009), arXiv:0907.0894.