Cooperative spreading diseases in temporal networks

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The formalism of dynamical systems and network theory provides analytical tools for the research in spreading processes. In fact, simple models with three (Susceptible-Infected-Recovered, SIR) or two (Susceptible-Infected-Susceptible, SIS) possible states for the interacting nodes, allow to explore the role of topology in disease spreading.

This problem increases its complexity when considering not only interacting hosts, but also interacting diseases, accounting for whether cooperation or competition between different diseases. It has been shown that the cooperation scenario can change the global epidemic dynamics.

In this work, we implement cooperation between two diseases following SIR dynamics. This cooperation is introduced through a higher probability of getting infected with a new disease if an agent has suffered (or is suffering) from another disease; this is translated into a secondary infection probability q higher than the primary infection probability p. This simple model has been shown to exhibit first order transitions for several topologies characterized by a high abundance of long loops , in contrast with two-dimensional lattices, where this dynamics does not lead to abrupt transitions [1]. Here, we explore this dynamics in a static topology, finding some conditions for which, increasing the average degree, the transition leading to a epidemic state becomes discontinuous.

However, interactions in real world are not permanent, so more realistic models need to include temporality in the interaction pattern. Hence, we analyze the same dynamics in topologies which are similar to the previous static case, with the difference that now the network interactions are time dependent, finding that, for a slow varying network, the system experiences a continuous phase transition, while as the temporal network is modified in a faster way, a gap appears in the transition point, leading to an abrupt outbreak, and being maximum for the cases in which the networks are uncorrelated between two consecutive time steps (Fig. 1).

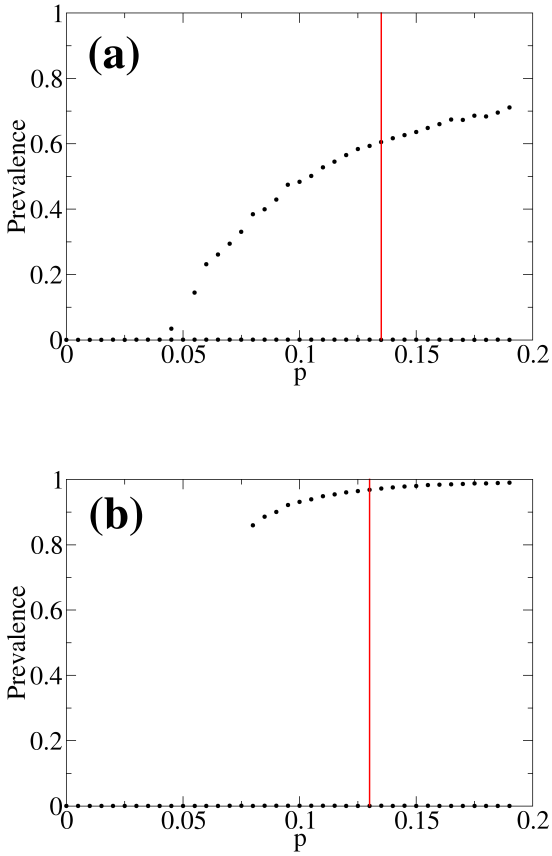

Figure 1: Prevalence of doubly recovered nodes versus the primary infection probability p for **(a)**, network varying slowly, and **(b)**, network varying fastly, approaching the regime in which two consecutive frames of the network are uncorrelated. We find two branches: one with low prevalence and another that grows, continuously from the low prevalence branch in **(a)**, and after a discontinuous transition in **(b)**. Red vertical lines indicate the critical point for continuous single disease phase transition in each topology. The secondary infection probability is $q = 0.99$.

[1] W. Cai, L. Chen, F. Ghanbarnejad and P. Grassberger, Avalanche outbreaks emerging in cooperative contagions, Nature Physics **11**, 936-940 (2015)