Robustness and fragility of the susceptible-infected-susceptible epidemic chain on networks

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Epidemic spreading is the one of the most prominent and widely investigated issues in network science, usually by means of agent-based stochastic models. One of the most basic but still puzzling epidemic model is the susceptible-infected-susceptible (SIS), which consists of agents lying on the nodes of a network where the infected individuals become spontaneously healed (susceptible) with rate $\mu$ and infects a susceptible contact with rate $\lambda$. There is a phase transition at an epidemic threshold $\lambda_c$ between a disease-free (absorbing) state and an active stationary phase, in which the epidemics persists. For random uncorrelated networks with a power-law (PL) degree distribution $P(k) \sim k^{-\gamma}$ the epidemic threshold is formally zero in the thermodynamical limit. Both real and computationally generated networks are finite, so the finite-size dependence is a fundamental issue and is frequently done by mean-field approximations that take into account the heterogeneity of the networks but truncating the dynamical correlations: the degree-based heterogeneous mean-field (HMF) and the individual-based quenched mean-field (QMF) theories are some examples. A criterion initially conceived for SIS model involves the mutual activation of hubs: if they remain active for times sufficiently long to infect each other, the epidemics is triggered by this mechanism. In this work, we investigate the robustness of this activation mechanism of the SIS dynamics by considering slightly modified versions of the standard SIS model preserving its fundamental properties. All models have the same thresholds in HMF and QMF theories while the criterion of mutual reinfection time of hubs for the modified models predicts a finite threshold in the thermodynamical limit for $\gamma > 3$, which is corroborated by statistically exact simulations on large synthetic networks. For $\gamma < 3$, we observed that the modified dynamics present a vanishing threshold in better agreement with HMF instead of QMF. For a collection of correlated real networks with different levels of heterogeneity, we observed that QMF theory reproduces accurately the thresholds of the original SIS dynamics but does not of the modified ones. For the modified dynamics, both theories present significant deviation from numerical estimated thresholds being HMF more precise. Our results relight the discussion of the conception of epidemic modeling of real systems and the choice of the suitable theoretical approaches.

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