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Stability of SIS Models over Directed Graphs: A Positive Systems Approach

We study the stability properties of a susceptible-infected-susceptible (SIS) diffusion model, so-called the n-intertwined Markov model, over arbitrary directed network topologies. As in the majority of the work on infection spread dynamics, this model exhibits a threshold phenomenon. When the curing rates in the network are high, the all-healthy state is the unique equilibrium over the network. Otherwise, an endemic equilibrium state emerges, where some infection remains within the network. Using notions from positive systems theory, we provide conditions for the global asymptotic stability of the equilibrium points in both cases over strongly connected networks based on the value of the basic reproduction number, a fundamental quantity in the study of epidemics. When the network topology is weakly connected, we provide conditions for the existence, uniqueness, and global asymptotic stability of an endemic state, and we study the stability of the all-healthy state. Finally, we demonstrate that the n-intertwined Markov model can be viewed as a best-response dynamical system of a concave game among the nodes. This characterization allows us to cast new infection spread dynamics; additionally, we provide a sufficient condition for the global convergence to the all-healthy state, which can be checked in a distributed fashion.