Dynamics on Networks: Competition of Temporal and Topological Correlations

Oriol Artime[1], Jose J. Ramasco[1] and Maxi San Miguel[1]

[1] Instituto de Fsica Interdisciplinar y Sistemas Complejos, IFISC (CSIC-UIB),
Campus Universitat de les Illes Balears, 07122 Palma de Mallorca, Spain

Networks are the skeleton that support dynamical processes in complex systems. Their connections determine which elements interact with each another, and their structural properties condition the outcome of the system dynamics. Most empirical networks are, however, not static but continously changing in time. The node connections are themselves evolving as the dynamic process is taking place on the network. In some cases, both dynamics are coupled in which has been called co-evolution, but in many others the link activations are just a reflection of the finite capacity of the nodes to sustain interactions. As a generic empirical fact, it has been found that the inter-event times between consecutive interactions show statistical distributions with long-tailed decays. The activation patterns among elements in a network may be irregular or bursty and play an important role on the dynamics of processes. Information or disease spreading are paradigmatic examples of this situation. Besides burstiness, several correlations may appear in the process of link activation: memory effects imply temporal correlations, but also the existence of communities in the network may mediate the activation patterns of internal an external links.

In this work we study the competition of topological (community structure) and temporal (link activation) correlations and how they affect the dynamics of systems running on the network. We introduce a model such that correlations can be systematically added and their strength tuned. The procedure we propose to generate different activation patterns in the links is highly flexible. We perform the analysis with a theoretical expression for the inter-event time distribution and its conditional form. The framework is, nevertheless, general and admits any other functional forms for these distributions including those coming from empirical data. This is illustrated with an example using Twitter interaction data. We use two paradigmatic dynamical models: the SI and the voter models. We show that, when acting alone, topologically induced correlations tend to slow down the dynamics on the network, while temporal correlations speed it up. We prove that the origin of this acceleration is in the formation of what we call stable backbones, that allow for a more efficient communication of the elements of the system. In case of the SI, this brings a faster spreading in the network while in the voter model the persistence of the backbone induces the formation of ordered structures that pull the system towards consensus.

We also focus on how the presence of mixed correlations impacts model dynamics. We explore different ranges of strength of temporal and topologically induced correlations. Interestingly, when both types of correlations are present, as occur in most empirical networks, the final dynamics crucially depends on the mix. Temporal correlations can accelerate or delay the dynamics depending on how defined the

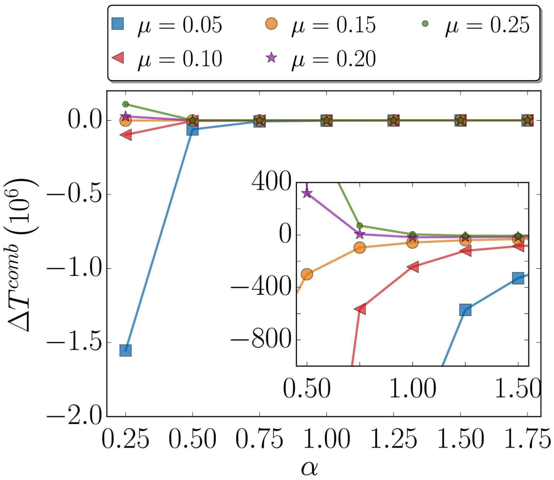

Figure 1: Bifurcation in the dynamics. In the x axis there is the temporal correlation strength and in the vertical one the time distance to reach the absorbing state between the null model and the actual correlated dynamics (positive region means acceleration and negative region means delay). We see that for different value of the topological correlation μ we can go continously from delay (strong communities) to acceleration (weak communities).

community structure is. We observe a community mixing parameter μ (a measure of how dense a community is) for which a bifurcation on the effect correlations on the model dynamics takes place (see Figure 1). This point changes with the difference between the activation patterns of the links internal and external to the communities but its presence seems to be quite generic. The closer is the link activation between both types of links, the strongest has to be the community structure to find the bifurcation.

To summarize, we present a general framework to include realistic properties of empirical networks through temporal and topological correlations. We exhaustively study how the correlated instances of dynamical models behave when compared to null models. When correlations come alone, the outcomes are straightforwardly identified. When correlations are mixed, nevertheless, the final behavior depend on the combination of the temporal activation pace and how well connected are the communities. We believe that the results we obtain and the mechanism behind them are far from trivial and they are fundamental to have a deeper understanding on dynamics on realistic networks.

The complete article can be found in the [1].

[1] Artime, O., Ramasco, J.J., San Miguel, M., https://arxiv.org/abs/1604.04155 (to appear in Scientific Reports).