Complex Cooperative Networks through Evolutionary Preferential Attachment

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Recent studies have shown that well-mixed models, lattices and spatial models do not correctly describe the backbone of complex systems. The ubiquity in Nature of the so-called scale-free (SF) networks has led scientists to propose many models aimed at reproducing the SF degree distribution[1]. Most of the existing models for network generation are based on growth rules that depend on the instantaneous topological properties of the network and therefore neglect the connection of the structural evolution and the particular function of the system.

On the other hand, a paradigmatic case study of the structure and dynamics of complex systems are social networks. In these systems, it is particularly relevant to understand how cooperative behavior emerges. The emergence of cooperation in the general framework of evolutionary game theory in natural and social systems has been the subject of intense research recently[2–4]. The results show that if individuals only interact with their neighbors, cooperation dominates over defection in SF networks. But, how cooperative behavior can naturally give rise to SF networks?, and what are the mechanisms that shape the system's structure?

In this work we analyse the growth and formation of complex networks by coupling the network formation rules to the dynamical states of the elements of the system. Specifically, we consider that the nodes of the network are individuals involved in a Prisoner's Dilemma game and that newcomers are preferentially linked to nodes with high fitness, being the latter proportional to the payoffs obtained in the game. In this way, an element's fitness is not imposed as an external constraint, but rather it is the result of the dynamical evolution of the system. Moreover, we show that the so obtained networks share many features with real-world systems such as the power law dependency of the clustering coefficient with the degree of the nodes, and hence can explain why heterogeneous networks are tailored to sustain cooperation. Finally, the model provides an evolutionary explanation for the origin of the both homogeneous and heterogeneous networks found in natural systems. Only when the selection pressure is weak, homogeneous networks can arise. On the contrary, when the selection pressure is high, scale-free networks are generated.

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