INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Sandpile is a generic model to study self-organized criticality (SOC) which provides a general mechanism for the emergence of complex behavior in many physio-hemical processes. On the other hand, the topology of many interacting systems can be modeled by complex networks which are usually compact, highly disordered, and maximally heterogeneous structures. The situation gets more intriguing when a complex dynamical process like SOC occurs on the top of a complex network. In order to investigate such situations, various sandpile models have been developed on several complex networks. Starting from the regular lattice small world network (SWN) has been developed adding shortcuts with a certain density. Dissipative versions of both the deterministic and the stochastic sandpile models have been studied on SWN. The steady-state critical properties of these newly developed sandpile models are characterized studying distribution functions of various avalanche properties. Three regimes of SWNs are identified: regular lattice regime (low shortcuts density), small world regime (intermediate shortcuts density), and random network regime (high shortcuts density). In the regular lattice regime, the sandpile dynamics is characterized by the respective scaling behaviour that usually occur on the regular lattice such as, Bak, Tang, and Wiesenfeld (BTW)-type correlated scaling for the deterministic model and the stochastic Manna scaling for the stochastic model. Whereas, in the random network regime, the dynamics is characterized by mean-field scaling for both the models. Interestingly, on small world regime, both the scaling behavior are found to coexist. In SWN regime, it is possible to identify certain characteristic size, area or time of avalanches below which the avalanche properties follow usual scaling on regular lattice and above which they obey mean-field scaling. Novel scaling forms of such characteristic properties of avalanches are developed analyzing several geometrical quantities of the toppling surface associated with an avalanche. Though the deterministic sandpile model does not obey finite-size scaling (FSS) on the regular lattice, it is found to obey FSS on the random network with MF exponents. On the other hand, the stochastic model is found to obey FSS on the regular lattice as well as on the random network with the respective exponents. FFS on random network appears to be an outcome of superdiffusive sand transport and uncorrelated toppling waves. In the SWN regime, however, none of the models obeys FSS because of coexistence of multiple scaling forms. A new co-existence scaling theory for more than one scaling forms on an SWN is developed and numerically verified for both the models. An ensemble of avalanche clusters consists of two types of avalanches, dissipative and nondissipative. If at least one sand grain is dissipated from the system during the evolution of an avalanche it is called a dissipative avalanche otherwise it is a nondissipative avalanche. Classifying the whole ensemble of avalanches into the ensemble of dissipative and nondissipative avalanches, the critical properties of the individual ensembles are determined on the regular lattice, random network, as well as on SWN for both the models. Nontrivial scaling properties, very different from those reported in the literature in the case of boundary dissipation, are obtained for the dissipative and nondissipative avalanches. Though in the thermodynamic limit the appearance of a dissipative avalanche would be a rare event, they mostly contribute to the catastrophic cascading effects and its critical behaviour is expected to play a crucial role in those effects. In order to control SOC on the complex network, a two-state sandpile model with preferential sand distribution to nodes of specific degrees is developed on a scale-free network with power-law degree distribution. Distribution of sands to extreme degrees is found to be an efficient and cost effective way of controlling self-organization as catastrophic cascades in terms of large avalanches which are found to be confined to certain restricted regions of the network in the scale-free regime. The results obtained in the thesis can be extended to understand various real-world problems that occur in society, infrastructure, finance, and many other fields.