Scaling in the recovery of cities from special events

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In this work we study the resilience and recovery of public transport networks from special events where a huge amount of people concentrates in a small part of the city. We use a packet based model of individuals going from origin to destination using the different lines of transport, taking into account the limited capacity of real transport networks For this purpose we will study the performance of the network with two different routing protocols, the shortest path routing where the individuals follow the shortest paths in the weighted network in any case and the adaptive routing with local knowledge where they are able to adapt their trajectory depending on the local information of the current stop.. Above the normal activity of the city we will study, depending on the routing protocol, the scaling of recovery times with the amount of agents in the perturbation and the place of the city as well as the average delay and the number of individuals and origins affected. We will begin by applying our model in 1D and 2D lattices and studying how the recovery time and delays change with the position of the perturbation and the amount of agents in it. The first we observe is that while the case of the shortest path routing the recovery of the networks with the amount of agents is always linear independently of the network in the case of the adaptive routing the structure of the network and the embedded space become relevant. In the case of the scaling in the recovery times, we solve analytically and use simulations to proof that it is related with the dimension of the embedded space, finding an exponent of 1 in the 1D case and 0.5 in the 2D case. While the average delay is not related to the place of the perturbation, in the case of the agents affected we find that the peripheral nodes have more influence on the number of origins and packets affected. Above this normal flow of people we will introduce different amount of agents in small places of the cities (200m x 200m) with a distribution of destinations according to the places of residence. When studying the recovery of cities we observe a scaling below 0.5 due to the different modes in public transport networks. While a public transport network with only one mode of transport has a dimension similar to a 2D lattice, the combination of modes with different speed and coverage increases the local dimension. We will propose a new metric of local dimension in networks which is related to the exponent governing the recovery of cities. We prove for different cities that our new definition of local dimension in weighted networks with capacity is able to predict the scaling and in a similar way the perturbations in peripheral areas affect a higher amount of origins and individuals.