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A hybrid strategy for network immunization

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ABSTRACT

Network immunization is an effective strategy for restraining virus spreading in computer networks and rumor propagation in social networks. Currently, lots of strategies are proposed based on topological structures of networks, such as degree-based and betweenness-based network immunization strategies. However, these studies assume that nodes in a network are homogeneous, i.e., each node has the same characteristic. However, more and more studies have revealed the heterogeneous characteristic of a network. For example, the activities of individual in a computer and social network play an important role in virus spreading and rumor propagation. Some active individuals can promote the outbreak of virus and the spread of a rumor. In this paper, a new network immunization strategy is proposed through combining the characteristics of network structure with node activities. Comprehensive experiments in both benchmark and synthetic networks show that our proposed strategy can restrain virus prorogation effectively.

1. Introduction

Network immunization is a very hot topic in the field of complex networks [1,2]. Lots of studies have proposed several strategies from the viewpoint of transmission dynamics and structural dynamics [3–5]. Generally speaking, an effective network strategy can restrain virus propagation through protecting a set of important nodes and blocking propagation paths. In order to estimate the performance of network immunization strategies, some universal simulation platforms are used to simulate a propagation process and compare the efficiency of immunization strategies in terms of the scale and speed of such propagation [6]. Therefore, the core work of network immunization strategy is to find out a set of important nodes which can effectively block propagation paths and further restrain the propagation.

Existing immunization strategies aim to find out a set of important nodes from the viewpoint of a network structure. These strategies believe that the function of a node in a network is determined by its location. Therefore, lots of strategies are proposed based on the topological feature of a network, such as degree-based strategies [7,8], betweenness-based strategies [6,9], and k-core-based strategies [10,11]. Although more than one feature of a network has been taken into consideration for designing a network immunization strategy [12], the immunized nodes selected by such a strategy are still based on the whole topological feature of the network.

However, more and more researches have found that a propagation in a network is also related to dynamic features of nodes [6,13]. More specifically, the dynamic feature of a node can affect both the scope and speed of a propagation. For example, the mobile virus propagation and the rumor spreading in a social network are activated by individual operational behaviors [14,15]. Their propagations are affected by both individual behaviors and topological structures of networks. In order to investigate the relationship between the dynamic feature of individual behavior and a propagation, more and more propagation models are proposed as platforms to simulate human-involved propagation processes [16]. From these models, we can conclude that dynamic features of nodes in a network are heterogeneous, which can affect the scope and speed of a propagation. Therefore, it is necessary to design a new immunization strategy considering the topological feature of a network and the heterogeneous features of nodes.

In this paper, we aim to propose a new network immunization strategy in which the importance of a node is determined by both its location in a network and dynamic activities within the node. Here activities of a node can be denoted as individual behaviors in the domain of email worm propagation and rumor spreading in computer and social networks, respectively. Specifically, our simu-

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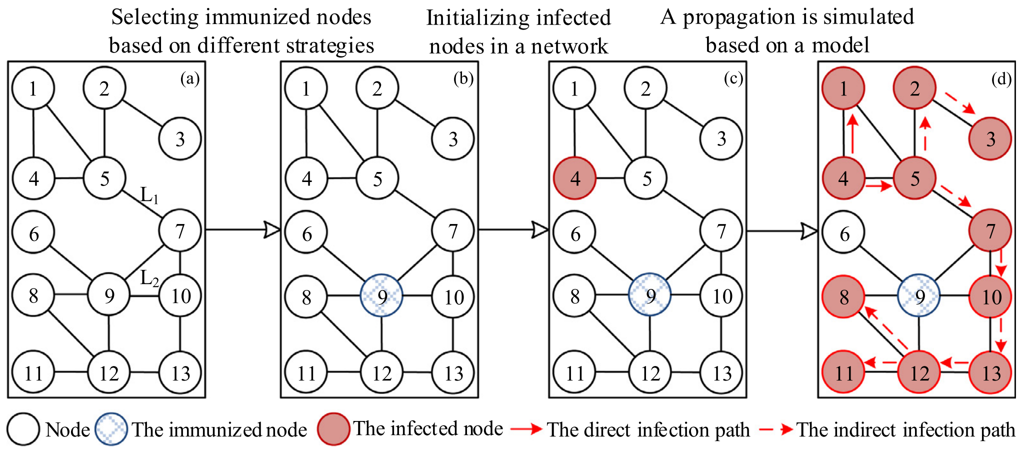

Fig. 1. Illustration for immunized nodes selected based on different immunization strategies. The immunized node can block paths of a propagation from v_5.

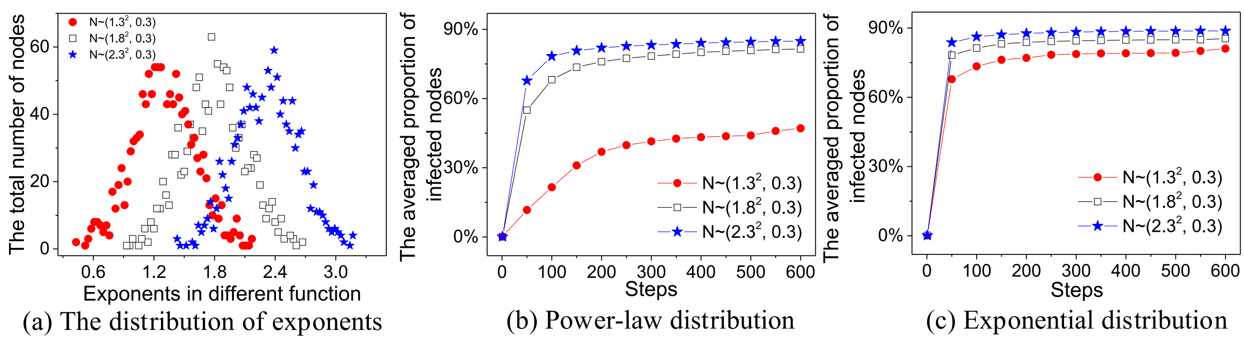

Fig. 2. Effects of nodes' activity on a propagation in the Enron email network. There are two random initial infected nodes. The activities of a node follow an power-law distribution or an exponential distribution during the diffusion process, while the exponents of nodes, which determine the shape of such distribution, follow a normal distribution as shown in (a). The parameters of three normal distributions are listed in the legends. The final propagation results, as shown in (b) and (c), show that the scale and speed of a propagation is related to the activities of nodes in a network. It is reasonable for us to design a new immunization strategy considering the activity of node.

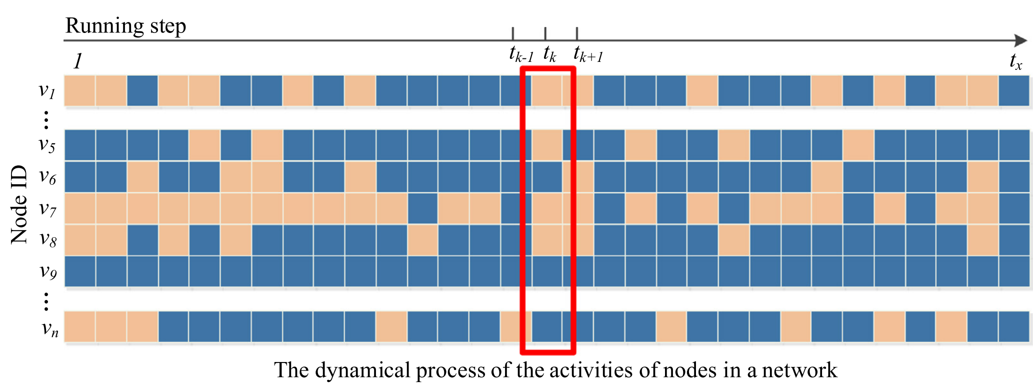

Fig. 3. Illustration of the dynamic change of activities among nodes in a network. The orange and light box denotes that the node is active at t_k in a propagation model and will be involved in a propagation process. Nodes highlighted by blue and dark boxes are inactive and will not be involved in the propagation at t_k. From this figure, we find that the influence of a node should take the activity of the node into consideration, since some nodes (e.g., v_9) will not be involved in the propagation process even if the centrality (e.g., degree) of these nodes is high based on the topological feature of a network. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

lations are implemented in single-layer networks, rather than networks with multi-layer structures, such as multiplex and interdependent networks [17,18]. However, our proposed strategy can be easily extended to multiplex and interdependent networks through combining the multi-layer structural features of networks with activities of nodes.

The remainder of this paper is organized as follows. Section 2 introduces the preliminary of our work and Section 3 formulates our proposed method. Comprehensive experiments are implemented in Section 4 in order to estimate the performance of our proposed strategy and compare it with others. Section 5 concludes our contribution.

2. Preliminary

2.1. The definition of network immunization

Many natural and engineering systems can be formulated as networks [19]. A complex network is formulated as an undirected graph $G = <V, L>$. V is a set of nodes (vertices) and L is a set of