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Research paper

Model for multi-messages spreading over complex networks considering the relationship between messages

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ABSTRACT

A novel messages spreading model is suggested in this paper. The model is a natural generalization of the SIS (susceptible-infective-susceptible) model, in which two relevant messages with same probability of acceptance may spread among nodes. One of the messages has a higher priority to be adopted than the other only in the sense that both messages act on the same node simultaneously. Node in the model is termed as supporter when it adopts either of messages. The transition probability allows that two kinds of supports may transform into each other with a certain rate, and it varies inversely with the associated levels which are discretely distributed in the symmetrical interval around original point. Results of numerical simulations show that individuals tend to believe the messages with a better consistency. If messages are conflicting with each other, the one with higher priority would be spread more and another would be ignored. Otherwise, the number of both supports remains at a uniformly higher level. Besides, in a network with lower connected degree, over a half of the individuals would keep neutral, and the message with lower priority becomes harder to diffuse than the prerogative one. This paper explores the propagation of multi-messages by considering their correlation degree, contributing to the understanding and predicting of the potential propagation trends.

1. Introduction

Propagation is a common natural phenomenon that occurs on wherever there are connections or communication possibilities. It covers the spread of rumors, disease, internet virus, public opinion, information and so on. Understanding such a spreading process is essential to the diverse fields of medical science, biology, chemistry, physics, and sociology [1]. Meanwhile, complex networks have been widely utilized for describing the spreading dynamic in human world [2,3]. The incorporated population structures feature between the random networks and regular networks, which dramatically alter dynamical properties of the diffusion process therein [4]. Noticeably, the diffusion of information in the complex social network is widely studied, which related to email contents, rumors, advertising messages, ideas, innovations and so on. Zhao et al. studied the effect of message spreading in epidemic preventive control [5]. Wang et al. discussed a diffusive logistic prediction model based on information diffusion over online social networks [6–8]. Trpevski et al explored the rumors propagation in multiple networks [9].

Currently, the SIR and SIS models are most studied in the field of propagation in complex networks, which are transfered from epidemics spreading models. The SIR model considers that infected people get lifelong immunity after recovery

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1007-5704/

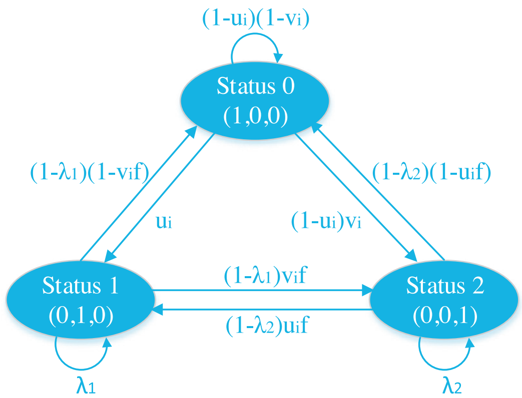

Fig. 1. The transition process of node status.

[10], while SIS model allows repeated infection [11]. DK model (named by Daley and Kendall), conceptually similar to the SIR model, is proposed by Daley and Kendall [12], in which population was divided into three types: ignorant, spreader and stifler, respectively corresponded to susceptible, infective and recovered people in SIR model. Further developing the DK model, Moreno assumes that ignorant may transforms into spreader with probability λ while meeting spreaders, and spreader may transforms into stifler with probability α sswhile contacting with other spreaders or stiflers [13].

The researches above are enlightened to our work, yet most of them focus little on the spreading of multiple messages except Trpevski et al. The latter explores the spreading of two types of rumors in synthetic networks and observes the fraction of nodes in the process of infection [9]. But the inadequacy of Trpevski's work lies in the separate propagation and the ignoring of potential correlation between rumors. In this paper, we develop a novel model based on SIS model and DK model to fill the vacuum. The stifler in DK model is identified as ignorant and may be infected once again in the new model. The correlation parameter is assigned with a discrete value to mark the relationship between messages. The population structure is mapped to a network, where nodes represent individuals and links represent their information-exchange relationships. The scale-free networked population and small-world networked population are mainly studied. By analyzing the inner relationships, we can better understand the spreading dynamics of multi-messages and predict the potential propagation trend.

This paper proceeds as follows. Section 2 defines the model formation and the required parameters. In Section 3, we develop numerical simulations on typical complex networks to investigate the behavior of model and analyze the results. The Section 4 concludes the paper then points out deficiencies and future directions.

2. Definition of the model

This section defines the model about how the multiple messages spread and influence each other. To simplify the formulation, the relationships among more than two kinds of messages are translated to the correlations between messages. The model is defined in the text below.

First consider a closed and mixed population of N individuals. The individual is represented by vertex (denoted as V) and contact is represented by edge (denoted as E). Then we get an undirected and un-weighted graph $G=(V, E)$. The nodes communicate with each other through directly or indirectly connected links. At each time step, the node $i(i \in [1, 2, ..., N])$ may be in either of possible states: susceptible or infected. Nodes are vulnerable and easy to be infected in the former states and possess the will to disseminate information in the latter states; If the neighboring node is susceptible, it would be infected at a certain probability; The infectious nodes may forget or ignore the messages and then change to the susceptible ones again.

Further, let A denotes the adjacency matrix of the graph G. λ_{ij} is the element of A. If there is a directly connected edge between vertex i and vertex j, set $\lambda_{ij}=1$; otherwise set $\lambda_{ij}=0$. At time t, each node i ($i \in [1, 2, ..., N]$) maybe in one of three statuses: the ignorant (status 0), the spreader of message 1 (status 1), the spreader of message 2 (status 2). The statuses are described as a status vector, containing a single 1 in the position, and 0 everywhere else. Let

$$Status_i(t) = [s_i^0(t), s_i^1(t), s_i^2(t)].$$

The state transition process is shown in Fig. 1. The probability function of each status is set by

$$\Pr ob(t) = [p_i^0(t), p_i^1(t), p_i^2(t)].$$

Evolution of the model is given by:

$$\begin{cases} P_i^0(t+1) = S_i^0(t)(1-u_i)(1-v_i) + S_i^1(t)(1-\lambda_1)(1-v_if) + S_i^2(t)(1-\lambda_2)(1-u_if) \\ P_i^1(t+1) = S_i^0(t)u_i + S_i^1(t)\lambda_1 + S_i^2(t)(1-\lambda_2)u_if \\ P_i^2(t+1) = S_i^0(t)(1-u_i)v_i + S_i^1(t)(1-\lambda_1)v_if + S_i^2(t)\lambda_2 \end{cases}, \quad (1)$$