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Rumor spreading model considering forgetting and remembering mechanisms in inhomogeneous networks

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ABSTRACT

The SIHR rumor spreading model with consideration of the forgetting and remembering mechanisms was studied in homogeneous networks. We further investigate the properties of the SIHR model in inhomogeneous networks. The SIHR model is refined and mean-field equations are derived to describe the dynamics of the rumor spreading model in inhomogeneous networks. Steady-state analysis is carried out, which shows no spreading threshold existing. Numerical simulations are conducted in a BA scale-free network. The simulation results show that the network topology exerts significant influences on the rumor spreading: In comparison with the ER network, the rumor spreads faster and the final size of the rumor is smaller in BA scale-free network; the forgetting and remembering mechanisms greatly impact the final size of the rumor. Finally, through the numerical simulation, we examine the effects that the spreading rate and the stifling rate have on the the influence of the rumor. In addition, the no threshold result is verified.

1. Introduction

Rumor is one form of human communication. Its spreading exerts significant influence on human affairs. It can cause unnecessary public anxiety and induce economic loss to affected countries [1–3]. Currently, the wide use of Internet virtually speeds up the dissemination of the rumors [4,5]. These years, various sorts of rumors sweep over China. In 2011, the rumor that the mangoes ripened by ethrel would do harm to people's health went around leading to a sharp drop in the purchasing price of mangoes and causing the farmers severe losses. Since the big earthquake happened in Japan last year, the rumors that iodized salt could protect people against the nuclear radiation and earthquakes would happen everywhere caused stirrings among the public. The Chinese government has recently taken action to regulate Internet rumors. The related Chinese government spokesman stated that from mid-March to mid-April in 2012, 210,000 rumor messages were deleted and 42 related websites were forced to close. Moreover, six people were detained in accordance with the law due to the bad social influence of their spreading rumors.

The first classical rumor spreading model, the DK model, was proposed by Daley and Kendal in 1965 [6], where people are divided into three groups, the ones who know and transmit the rumor, the ones who do not know the rumor, and the ones who know the rumor but do not transmit it. Besides, the rumor spreads through pair-wise contacts between spreaders and the other people. Maki and Thomson developed another classical model [7]. They linked rumor spreading with the spreaders directly contacting other people and proposed that when a spreader contacts another spreader, only the former one stops propagating the rumor. Afterwards, many researchers extended their study on rumor spreading based on the above two classical models [8–14]. Besides, lots of scholars researched rumor spreading considering the topology

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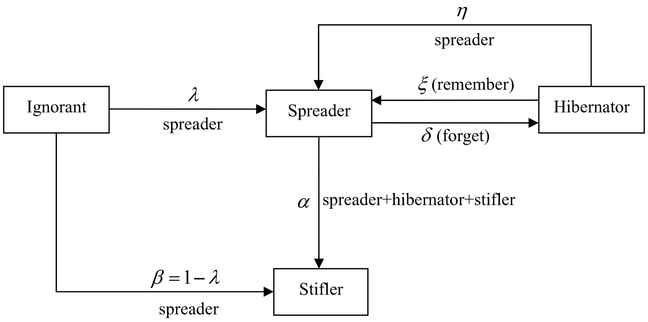

Fig. 1. Refined SIHR rumor spreading process.

properties of social networks [15–23]. Zanette [24,25] and Buzna et al. [26] applied the rumor spreading model to small-world networks and proved the existence of the critical threshold of the rumor spreading. Moreno et al. [27] examined the dynamics of the classical rumor spreading model on complex networks. Gu and Cai [28] and Gu et al. [29] introduced forget and remember functions to a two-state model and analyzed the effects on rumor spreading. Nekovee et al. [30] and Zhao et al. [31] modified the rumor spreading model with consideration of the forgetting mechanism. Zhao et al. [32] refined the classical rumor spreading model with consideration of the forgetting mechanism and the remembering mechanism and checked its dynamics in homogeneous networks.

Zhao et al. [32] investigated the dynamics of the rumor spreading model considering forgetting and remembering mechanisms in homogeneous networks. However, many real social networks are extremely close to inhomogeneous networks with a topology more complex than homogeneous networks. In this paper, we extend the research of the above model to inhomogeneous networks and examine its dynamics. In the next section, we refine the rumor spreading model in Ref. [32] by adding a realistic condition and make a description of the refined model in inhomogeneous networks. Afterwards, a steady state analysis is conducted in Section 3 and the no-spreading threshold result is achieved. Numerical simulations of the refined model in BA scale-free network are presented in Section 4, which show that the network topology and some related parameters have significant impacts on the rumor spreading, and verify the no spreading threshold result. Finally, conclusions are drawn in the last section.

2. Refined rumor spreading model

The rumor spreading model resembles the epidemic spreading model in the dynamics behavior. The rumor spreading model in Ref. [32], called the SIHR model, was named according to the classical epidemic spreading model, where S stands for Spreaders (similar to Infective), I represents Ignorants (similar to Susceptible), H means Hibernators and R denotes Stiflers (similar to Removed). The refined SIHR rumor spreading model in inhomogeneous networks is described in the following way. We consider a closed and inhomogeneous mixed population with N individuals who can be in four different states, corresponding to ignorant, spreader, hibernator and stifler. Ignorants are comprised of individuals who have not heard of rumors and are susceptible to be informed of the rumor. Spreaders are those who spread rumors. Hibernators consist of individuals who are transformed from the spreaders due to the forgetting mechanism and can be turned back to spreaders due to the remembering mechanism. Finally, stiflers are composed of individuals who have heard the rumor but do not spread it any more. The spreading process goes forward through direct contacts of the spreaders with the rest of the population. It constructs an undirected social interaction network $G = (V, E)$, where V and E denote the vertices and the edges, respectively. The rumor spreading rules are linked with the following. When a spreader contacts an ignorant, the last one becomes a spreader with probability λ and becomes a stifler with probability β. Here, to be more realistic, $\lambda + \beta = 1$ is added to the previous model due to the fact that when informed of the rumor the ignorant cannot stay ignorant but either transmit the rumor or do not. Spreaders spontaneously forget the rumor and switch their state to be the hibernators at the rate δ as result of the forgetting mechanism. And hibernators spontaneously remember the rumor and become the spreaders at the rate ξ called spontaneous remembering rate. Besides, a hibernator switches to be a spreader with probability η (i.e. wakened remembering rate) when contacting a spreader. When a spreader contacts a spreader, hibernator or stifler, the former one turns into a stifler with probability α. The above rumor spreading rules virtually depict the following phenomenon: Whether individuals accept a rumor or not depends on the urgency or credibility of the rumor; the spreaders lose interests in spreading the rumor when they are aware that the rumor is out of date or false through contacting with the informed individuals (i.e. spreaders, hibernators and stiflers) [30]; the spreaders could forget the rumor and then remember it [32]. The refined SIHR rumor spreading process is shown in Fig. 1.

Denote by $S(t)$, $I(t)$, $H(t)$ and $R(t)$ the density of spreaders, ignorants, hibernators and stiflers at time t, respectively. $S_k(t), I_k(t), H_k(t)$ and $R_k(t)$ represent the density of spreaders, ignorants, hibernators and stiflers with connectivity k at time t, respectively. We have that $S(t) = \sum_k S_k(t)P(k)$ with $P(k)$ the degree distribution and so do $I(t), H(t)$ and $R(t)$. In addition, $S_k(t) + I_k(t) + H_k(t) + R_k(t) = 1$ and $S(t) + I(t) + H(t) + R(t) = 1$. The mean-field equations read as