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The impact of group propagation on rumor spreading in mobile social networks

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HIGHLIGHTS

- A model for analyzing rumor spreading in social networks with groups is proposed.
- Group propagation heavily increases the rumor spreading speed and spreader size.
- Having large groups is more effective on rumor spreading than having more groups.
- Network topology does not significantly influence grouped rumor spreading.

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ABSTRACT

A group in a mobile social network is normally considered as a particular contact in which invited individuals can share messages. People in a mobile social network sometimes share rumor messages with the contacts in the group that are not necessarily familiar with them. They normally get the rumor messages posted by different users and forward them to the other individuals or groups. There are some models for analysis of rumor propagation in mobile social networks. However, none of them have considered the concept of rumor propagation into groups of nodes. In this paper we study the rumor spreading in mobile social networks when the concept of group propagation is also considered. For this purpose, we extend the SIR information propagation model and investigate the impact of group propagation on the dynamics of rumor spreading process. We conduct steady-state analysis to investigate the basic reproduction number of the rumor spreading in the model. Furthermore, agent-based modeling and simulation is used to analyze the final size of the rumor under various group propagation rates as well as the impacts of group parameters on group spreading dynamics. The simulation results obtained by Monte Carlo method show that group propagation effectively increases the rumor spreading speed. We show that having large groups is more effective on rumor spreading than having more groups. Furthermore we analyze the influence of network structure on rumor spreading when group propagation is considered. For this purpose, two Erdős–Rényi and Barabási–Albert models of social networks are considered and it is shown that rumor spreading behavior in these networks have no significant differences when we have rumor propagation in groups.

1. Introduction

Mobile social networks have become an important platform for information propagation in recent years. The openness of these networks enables users to spread rumors around the Internet [1]. Rumor is defined as a form of information which

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is known as unverified statement [2]. Investigation of the dynamics of rumor propagation is an interesting research topic in recent years. The main characteristic of a rumor is the capability of fast growing and uncontrollable spreading [3].

A group in a mobile social network is normally considered as a particular contact in which invited individuals can share messages. All users in a mobile social network are able to create and manage social groups and invite their friends to the groups. The group members in turn can invite other people to the group afterward. So a group easily will turn into a small community that people may not directly know each other. This way, although some group members may not be directly in contact with others, but each message (including rumor messages) sent to the group is seen by all of the members. As a social habit, users in social networks get the rumor messages posted by different users and forward them to the other individuals or groups.

SIR (Susceptible–Infected–Removed) model is an epidemic disease propagation model proposed by Kermack and McKendric [4]. Due to the similarity between the rumor dissemination and the epidemic spreading, most of the rumor spreading models are derived from the SIR model. The first classical rumor propagation model, DK, was proposed by Dally and Kendal [5] based on the SIR model. In this model, the population is divided into three parts: those who do not know the rumor (Ignorant), those who have heard the rumor and spread it (Spreader) and those who know the rumor but they have stopped spreading (Stifler). Maki and Thompson modified DK model and proposed another classical model named as MK [6]. Many researchers extended DK model and its variant MK to get insight into the rumor spreading mechanism [7,8]. Most relevant works assume that individuals can only transmit rumor to other directly connected nodes e.g. direct friends [9–12]. However, in some social networks (such as Telegram, WhatsApp, WeChat, etc.) which support group creation and management by the users, individuals not only can transmit rumor to directly connected nodes, but also can transmit rumor to those who are not directly connected to them and hence may not be familiar with them. Therefore in such social networks, the rumor propagation process is influenced by social groups. As much as we know there is no work yet to consider the concept of group propagation in modeling and analysis of rumor spreading.

In this paper, SIR epidemic model is adapted to study the impact of group propagation in dynamics of the rumor spreading process in both homogeneous and heterogeneous networks. For this purpose, we introduce the dynamical equations of the systems and conduct steady-state analysis to investigate the basic reproduction number of the rumor spreading in both networks. We use Jacobian method and drive the eigenvalues of the Jacobian matrix to analyze the stability of the system in homogeneous network and we use next-generation matrix method [13] for finding the basic reproduction number in heterogeneous network. Also we conduct agent-based simulation using NetLogo [14] to investigate the final size of the rumor under various group propagation rates as well as the impacts of group parameters on group spreading dynamics in Erdős–Rényi (ER) and Barabási–Albert (BA) as two structurally different models of social networks. The results show that group propagation has a great impact on rumor spreading process and we analyzed the sensitivity of different group variables on this impact. Especially we found that having large groups is more effective on rumor spreading than having more groups. The simulations on both ER and BA networks indicate that influences of the structure of these networks on the behavior of rumor spreading with group propagation have no significant differences.

The rest of this paper is organized as follows: In Section 2 the proposed rumor spreading model is introduced. In Section 3 the simulations and analysis of the effects of group propagation on rumor spreading are conducted. Finally, we conclude the paper in Section 4.

2. The proposed rumor spreading model

In this section our rumor spreading model for considering group propagation is introduced. We extend SIR to model rumor propagation in mobile social networks when group propagation is available. The network is considered either as an undirected homogeneous, or heterogeneous graph with N labeled nodes and E edges (We will formulate the model for both types of networks later in this section). The mean degree of the graph is also assumed to be $\overline{K}$. The nodes represent either the individual users or groups in the social network (based on the corresponding labels) and the edges represent the contacts between users or between users and the groups to which they belong. Time is assumed to be discrete and at each time step, each individual user node is in one of the following three states:

- Ignorant (I): the nodes who have not yet received the rumor.
- Spreader (S): the nodes who have received the rumor and are capable of spreading it to ignorant nodes.
- Stifler (R): the nodes who have received the rumor but have no interest to spread it.

Each individual user node can propagate rumor through either other individual nodes or social groups to which he/she belongs. A group in social network is a set of users whose messages can be seen by each other. Whenever a message is received by a group node, it is automatically propagated to all of the nodes who are members of this group. The members of a social group may not be necessarily friends i.e. they may have no direct contact together. Thus, it is possible that two non-friend nodes in the social network send a message together via the group in which they are both members.

Fig. 1 shows the model for state changing in an individual node with group consideration. As shown in Fig. 1, a spreader in contact with another spreader or stifler (shown by SS and SR in the model respectively), may become uninterested in rumor propagation and changes to stifler with probability η. Also a spreader under the influence of the messages received in his/her groups (probably shared by a spreader individual user in that group) may become a stifler with probability ε (shown by Group label). Similarly an ignorant in contact with a spreader or under the influence of its group might change to a spreader with probability τ or γ respectively.