Physica A 471 (2017) 126–134

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Gossip spread in social network Models

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HIGHLIGHTS

- The *T* and *Vaz* social network models are compared.
- Both models capture the relationship between gossip spread and degree.
- The *Vaz* model is more consistent across the parameter space.
- The *Vaz* model better captures the expected values and variability of gossip spread.

ARTICLE INFO

Article history:
Received 28 June 2016
Available online 2 December 2016

Keywords:
Social network
Gossip
Spread
Variability

ABSTRACT

Gossip almost inevitably arises in real social networks. In this article we investigate the relationship between the number of friends of a person and limits on how far gossip about that person can spread in the network. How far gossip travels in a network depends on two sets of factors: (a) factors determining gossip transmission from one person to the next and (b) factors determining network topology. For a simple model where gossip is spread among people who know the victim it is known that a standard scale-free network model produces a non-monotonic relationship between number of friends and expected relative spread of gossip, a pattern that is also observed in real networks (Lind et al., 2007). Here, we study gossip spread in two social network models (Toivonen et al., 2006; Vázquez, 2003) by exploring the parameter space of both models and fitting them to a real Facebook data set. Both models can produce the non-monotonic relationship of real networks more accurately than a standard scale-free model while also exhibiting more realistic variability in gossip spread. Of the two models, the one given in Vázquez (2003) best captures both the expected values and variability of gossip spread.

1. Introduction

Gossip is a pervasive feature of the human condition. Defined broadly as talk about social activities it accounts for about two-thirds of speaking time [1] and has been proposed to serve many functions, including cultural learning [2]; indirect aggression [3]; and social group bonding [1]. From a psychological perspective, gossip has been studied developmentally [4]; in terms of its effect on group members [5]; and as an individual differences variable [6]. However, gossip is an inherently social phenomenon [7] and thereby also depends intimately on the structure of relationships between people.

The structure of a social network and the way gossip spreads from one person to the next both imply constraints on how far gossip can spread in a social network. In this context, the relationship between the number of friends of a person and how far gossip about that person is expected to spread is not entirely obvious. Intuitively, one might expect that more friends should be associated with greater expected spread of gossip. However, based on a simple model of gossip transmission, Lind et al. [8] found expected relative spread of gossip to be a non-monotonic function of number of friends, both for a real

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http://dx.doi.org/10.1016/j.physa.2016.11.132
0378-4371/

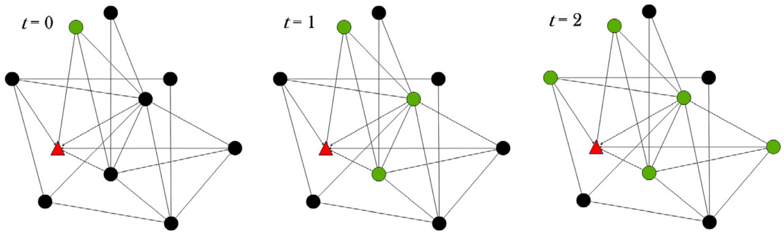

Fig. 1. Spread of gossip through a network. At time $t = 0$ the initial gossiper (green circle) has gossip information about the target (red triangle). At $t = 1$ the gossip spreads to common friends of the gossiper and target. The gossip continues spreading in the same way until no new friends can be reached ($t = 2$). The fraction of target friends reached by the gossip is the spread factor for the target, given a specific initial gossiper. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

social network data set and for the commonly studied Barabási–Albert (BA) model [9]. For people with very few friends, the expected proportion of friends reached by gossip is high, decreasing up to a certain number of friends, from which point the expected proportion of friends reached by gossip increases. Hence, in a sense, the optimal number of friends to reduce gossip spread is neither the minimal nor maximum number of friends, but somewhere in between.

The work of Lind et al. [8] was not conducted with the explicit purpose of modeling social networks. Indeed, the BA model is not viable as a social network model in general. Social networks typically exhibit greater levels of clustering, assortativity and community structure compared to the BA model. In the current work we set out to investigate spread of gossip in models explicitly designed to capture these distinguishing features of social networks. To this end, we simulate gossip spread in two different social network models [10,11] and in a real social network Facebook data set. We explore the parameter space of both models and we also fit the models to the Facebook data. The basic question is to what extent the social network models capture the relationship between gossip spread and number of friends. In this context, we consider not only the expected spread of gossip, but also variability in gossip spread within a network. An overall simple summary of our results is that the investigated social network models capture these features of gossip spread well and beyond that of the BA model.

A network consists of *nodes* and *edges* connecting the nodes. In the current simulations the nodes represent people and the edges represent friendship relations among people in a social network. Friendship is here treated as a symmetric relation: if A is a friend of B, then B is a friend of A. The network representing friendships is then undirected in that an edge connecting two nodes represent a symmetric relation. All friendship relations are given the same weight so the network is also unweighted. The degree k of a node is given by the number of edges connected to it and the degree distribution $P(k)$ is given by the relative frequency of nodes with degree k in a network. The extent of gossip spread for a person can be evaluated by the *spread factor* f [8]. Suppose there is some gossip information about a person being spread throughout the network. The quantity f is then defined as the number of people reached by the gossip divided by the maximum number of people that could theoretically be reached by it. Thus, the spread factor is a relative measure as it designates a proportion.

An example of gossip spread may be helpful. Consider the network in Fig. 1. At time $t = 0$ we have a person (green circle) possessing some gossip information about a target (red triangle). One of the gossip models investigated by [8] consists in gossip spreading from the initial gossiper (green circle) to friends common to the gossiper and the target. Thus, at time $t = 1$ in Fig. 1, the information has spread to two additional persons. This spreading continues in the same way from the persons now possessing the gossip information, until no new persons can be informed by the gossip. At this point we ask what proportion of the target's friends have come to know the gossip and we have the spread factor for the target node starting from one particular gossiper, which turns out to be 1 at $t = 2$ in Fig. 1. In order to get the overall spread factor f for a target we compute spread factors starting from each friend of the target as the initial gossiper and take their average. This gives the expected proportion of friends of the target being reached by gossip starting from a random friend of the target. In the next section we evaluate gossip spread in an empirical Facebook data set and, for the sake of comparison, in the BA model.

2. Gossip spread in a real network and the BA model

The real social network data set we use consists of a publicly available anonymized Facebook network data set, which was obtained by [12] by crawling the New Orleans regional Facebook network on two occasions in 2008 and 2009. The network is an undirected unweighted friendship network and we use the largest connected component amounting to $N = 60\,687$ nodes and $E = 690\,071$ edges. We simulated gossip spreading through this network the same way as described in Fig. 1, so that gossip is constrained to spread only among common friends of target and gossipers. Although this constraint is not likely to be strictly true for real networks, it has been observed that sharing of friends is associated with a greater tendency for negative gossip [13].

Fig. 2(A) shows the expected spread factor f as a function of degree k and the resulting non-monotonic relationship where f first decreases and then increases. This relationship is very similar to that observed by Lind et al. [8] for a different data set. It can also be noted that the spread factor f for individual nodes (gray circles) scatters over large ranges for different k, with tighter ranges as k gets very small (which is trivial) or very large. The degree distribution in Fig. 2(B) has a mean degree $\bar{k} = 23$, a median degree $\tilde{k} = 9$ and is heavily skewed but not strictly power-law.