A Social Network Information Propagation Model Considering Different Types of Social Relationships

Changwei Zhao, Zhiyong Zhang, Hanman Li, and Shiyang Zhao

Henan University of Science & Technology, Luoyang, China
zhao_chw@163.com, z.zhang@ieee.org

Abstract. In social networks, information are shared or propagated among user nodes through different links of social relationships. Considering the fact that different types of social relationships have different information propagation preference, we present a new social network information propagation model and set up dynamic equations for it. In our model, user nodes could share or propagate information according to their own preferences, and select different types of social relationships according to information preferences. The model reflects the facts that users are active and information possess propagation preferences. Simulation results proved the validity of the model.

Keywords: social network service, propagation model, dynamic equation, digital rights management.

1 Introduction

At present, a social networking service (SNS) has gained significant popularity and is among the most popular sites on the Web [1]. It has been an important platform to build social networks or social relations among people who, for example, share or propagate interests, activities, backgrounds, or real-life connections [2]. Different from the traditional web services, which are largely organized around content, SNS is user-centered, and information is disseminated via social relationships among friends. The research of information dissemination mechanism in SNS has important applications in many fields, such as opinion spread, disease control, digital rights management [3,4], and so on. In social networks, users, social relationships and information are three essential items, and users are described as nodes, social relationships of friends are called edges or links in networks graphs. Users are publishers or disseminators about information, and relationships are transmission path of information. Information is propagated through relationships among friends. If the number of edges between any two nodes is greater than two, we call the network graph as a multigraph. Comparing with the diffusion model of disease [5, 6], computer viruses, opinions, and rumor [7], the propagation model of SNS has its own characteristics. First, users might recognize activity the feature of information which will be shared or propagated, and select an appropriate path to disseminate it according its feature rather than to share indiscriminately it on all relationships. Moreover, there are many types of relationships among users, such as friends, colleagues, acquaintances, classmates, etc. And a user

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maybe belongs to different types of it. Also, the preference of transmission path is a basic character of information. Considering different relationship types of SNS and information dissemination preference, we present a new information dissemination model of social network, and the dynamic behavior of it is analyzed.

2 Related Works

The research of social networks pertains to the fields of complex networks. A complex network is a graph with non-trivial topological features. The study of complex networks is a young and active area of scientific research inspired largely by the empirical study of real-world networks such as computer networks and social networks. Erdős–Rényi networks, scale-free networks and small-world networks are three kinds of it. ER is a full random graph. Scale-free networks [8] and small-world networks are characterized by specific structural features—power-law degree distributions for the former and short path lengths and high clustering for the latter. Many real-world networks connection meets the feature of power-law degree distributions. In [1, 9], degree distribution, clustering coefficient, clustering coefficient and vertex degree correlation coefficients of social network were analyzed. In modeling of SNS, referring dynamics of infectious disease and using complex networks theories, [10] presented an online social network information dissemination theoretical model. However, in this model, neither preferences of information dissemination nor types of social relationships are considered. All information will disseminate on all type links and have same ability of propagating. Trust is basis of transaction among users in social networks, and is basis of information dissemination too. It is a very common situation, which multi-type relationships connect two user nodes. So far as we know, [11] first noticed this phenomenon, and a hybrid approach is presented for calculating edge trust weights. However, relationships between information dissemination preference and types of links are not concerned. Taking into account the fact that user node is an active node and the user will not share or propagate information randomly, we proposed a new model, in which user activity select suitable edges for propagating or sharing information according information features, there, we called information features as information preference. The model can accurately reflect information dissemination characteristics in SNS and is more consistent with real situation.

3 Model

3.1 Topology of Multi-type Relationships SNS

In a multigraph of social networks (as shown in Fig.1 left), according types of links, it can be transformed into several subgraphs of unique link. And corresponding nodes can share information in different type graphs. As shown in Fig.1, both subgraphs are disconnectivity, but information may spread on all network through users sharing information on different types of link.

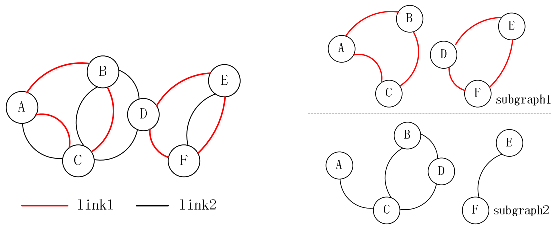

Fig. 1. Mulitgraph vs subgraph

3.2 Information Dissemination Mechanism

In SNS, users are publishers or disseminators of information, and information are spread via different types of relationships. Manner of user spreading information is active. Users select suitable path according information preference. User nodes can be divided into three classes according to function and state of it: interest node (I), disinterest node (D) and propagation node (P). For new information, propagation node is the node which receive the information from neighborhood nodes and possess dissemination capability; Interest node is the node which is a new node and has interest in it, and an interest node may become a propagation node according to a certain probability; if an interest node has not propagation interests, it will become a disinterest node. We define the following dissemination rules:

1. Information I has different dissemination preference I_p, $I_p=[p_1,p_2,\ldots p_n]$, $p_m \in [0,1]$,m=1,2,…,n. m is type of social relationships. p_m is dissemination preference of I about m and independent each other.
2. For different m and I, propagation node P select links whose type is m with probability p_m and disseminate information I with probability p_t, where p_t is dissemination probability. Once propagation nodes contact with interesting nodes, the latter will convert into propagation nodes and the former will convert into disinterest node with probability 1. That is, user nodes will not repeat sharing or propagating same information.
3. Propagation nodes do not always stay in the state of dissemination. It will become disinterest nodes with probability p_d, where p_d is disinterest probability. In other words, user nodes have no interest in disseminating information I, and information I cannot be propagated for ever.

3.3 Dynamic Equations of Model

Assume the state of user node N is interesting at time t. p_{ii} is probability of remaining interesting state in time slice$[t, t+\Delta t]$, for simply, Δt is defined as one cycle time of changing or remaining state. p_{ip} is changing probability from interesting state to propagation state, and we have: $p_{ip}=1-p_{ii}$.

For information I with preference I_p, We assume user node N has k links, and has k_m links which permit to types m, then $\sum k_m = k$. g_m is the number of propagation nodes, which links to node N directly via the links of type m at time t. then:

$$p_{ii} = \prod_{m=1}^{n} [(1-p_m)(1-p_t)]^{g_m} \tag{1}$$

Assume type of social relationships m is independent and obey uniform distribution, and total type of social relationships is n. Then, for nodes whose degree is k, the probability is k/n those one links permits to type m. k_m, the number of links which permit to type m, obey binomial distribution:

$$P(k_m) = \binom{k}{k_m}\left(\frac{k}{n}\right)^{k_m}\left(1-\frac{k}{n}\right)^{k-k_m} \tag{2}$$

Assume g_m obey binomial distribution too, then:

$$P(g_m) = \binom{k_m}{g_m}(\omega_{km})^{g_m}(1-\omega_{km})^{k_m-g_m} \tag{3}$$

Where, ω_{km} is connected probability from propagation node to interesting node in networks of type m. where:

$$\omega_{km} \approx \sum_{k'} p(k' \mid k)\binom{k}{k_m}\left(\frac{k}{n}\right)^{k_m}\left(1-\frac{k}{n}\right)^{k-k_m} \rho^{p}(k',t) \tag{4}$$

$p(k'|k)$ is the degree of correlation function, and represents conditional probability of adjacent nodes whose degrees are k and k′ differently. In social networks, $p(k'|k) = (k'p(k'))/\bar{k}$ [8]. $\rho^{p}(k',t)$ is propagation nodes density, whose degree is k′ at time t.

From formula (3) and (4), we can get average maintenance probability of interest node, whose degree is k, at time slice $[t, t+\Delta t]$. For type of m:

$$\bar{p}_{ii}(k_m,t) = \sum_{k_m=0}^{k}[P(k_m)\sum_{g_m=0}^{k_m}\binom{k_m}{g_m}(1-\Delta t \cdot p_t)^{g_m}(\omega_{km})^{g_m}(1-\omega_{km})^{k_m-g_m}] \tag{5}$$

For all networks, average maintenance probability is :

$$\bar{p}_{ii}(k,t) = 1 - \prod_{m=1}^{n}(1-\bar{p}_{ii}(k_m,t)) \tag{6}$$

Assume N(k, t) is the total number of nodes whose degree equal k at time t, and I(k, t), D(k, t), P(k, t) is the number of interesting, disinterest and propagation nodes differently. Then we have:

$$N(k,t) = I(k,t) + D(k,t) + P(k,t) \tag{7}$$

In Δt at time t, simply we set Δt=1, then the variation of interesting node is:

$$\Delta I(k,t) = \bar{p}_{ip}(k,t) \cdot I(k,t) = \prod_{m=1}^{n}(1 - \bar{p}_{ii}(k_m,t)) \cdot I(k,t) \tag{8}$$

Using ruler (3), we can conclude the variation of propagation node is:

$$\Delta P(k,t) = (1 - p_t - p_d) \cdot P(k,t) \tag{9}$$

From (7), (8), (9), we can get:

$$\Delta D(k,t) = -\Delta I(k,t) - \Delta P(k,t) \tag{10}$$

(8), (9) and (10) compose dynamical equations of social network information propagation model.

4 Experiments

4.1 Data

In experiment, we first generate data of social relationships according to distribution and connection characteristics of actual social network data. The data includes two different types of link, which have same distribution, power-law distribution. The networks parameters as follows: The total number of nodes is 9971, the average degree is 24.92, the maximum degree is 713, the clustering coefficient is 0.019, and the degree assortativity is 0.094.

4.2 Experiment

In order to verify the model's validity, we conducted several experiments and analyzed the results. In our experiment, we set initial propagation node number equal 1, the others are interesting nodes.

Networks Stable State vs. Information and User Preference

When networks are stable, number of interesting node reflects the dissemination range of information. The results of number of interesting node vs different preferences are shown in Fig. 2.

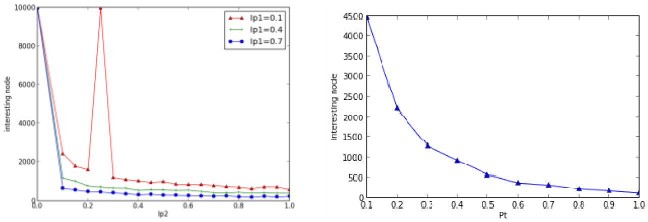

Fig. 2. Number of interesting node vs different preference

As the Fig.2 show: networks stable state is not only related to the network topology, but also the types of relationships, the information transmission preference and the users transmission preference. From above, we can draw that not all information can disseminate on whole net, the dissemination range is related to the information propagation preference. When the network is not connected with single relationship, the information can effectively increase its dissemination range through various relations.

Transmission Duration vs. Transmission Preference

Transmission duration refers to the time slice from the first time of information propagated to the system stability. Due to the randomness of transferring information of users, results which information are propagated less than twice are omitted. Parameter Setting: p_t=0.7, p_d=0.3. Under different transmission preference, transmission duration results are as Fig.3, and the number of failures is as Fig.4:

From Fig.3 and 4, we can draw that there is a relation between the transmission preference and the information transmission duration. The preference value increases, the duration decreases. That is, the information reaches its stability in a short time. At the same time, the dissemination cannot fail easily and has a better possibility to transmit on whole network.

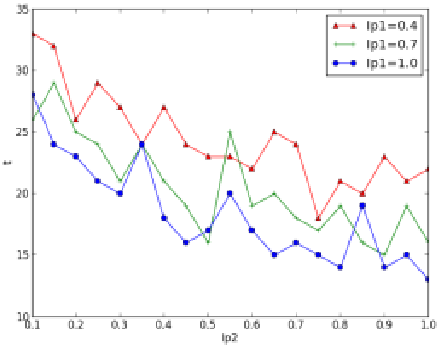

Fig. 3. Transmission duration VS Ip

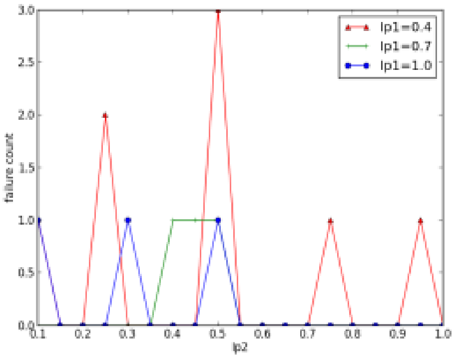

Fig. 4. Transmission failure VS Ip

Networks Stable State vs. Initial Nodes Degree

The information transmission preference I_p=[0.6,0.6], user transmission preference p_t=0.7. Initial nodes degree is 101, 324, and 558 differently. When networks are stable, number of disinterest indicates as Fig.5:

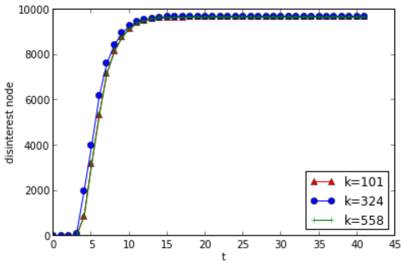

Fig. 5. Networks stable state vs initial nodes degree

As the Fig.5 shows: the initial node degree has little influence on the internet stability. This is determined by the power-law distribution and the high connectivity of social network. From above, we can draw that the network stable state is related to the transmission preference of the user and information instead of the initial node.

5 Conclusion

In this paper, a new social network information propagation model is represent. The model can reflect the facts that users and information propagated have different preference in different types of relationships, which link all user nodes. It is consistent with real social network in information dissemination, and it is a suitable model of social network information transmission. Although in this paper, information transmission preference is defined, but no real information be mapped to its spread preferences. Next step, we will study how to map text information, multimedia information to its preference, and provide forecast for real information propagation.

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