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Information Dissemination and Control Models in Complex Network

Li Juan*, Zhou Xueguang, Chen Bin
Naval University of Engineering, Wuhan, 430033, China, Ph./Fax: +86-02783443541
*Corresponding author, e-mail: lijuan770107@126.com

Abstract

In order to well understand and control the information dissemination in the complex network, Increasing Trust SI model and SIP model have been built to represent the peoples' interaction during information dissemination. By introducing and computing the trust degree of the net nodes, the process of information dissemination can be truly represented following increasing trust rule. Simulation experiments reveal that the informations can be quickly broken out in ER model, NW model and BA model due to the small world characteristic of complex networks. To prevent bad information disseminating, SIP model with "Persuasion" mechanism is presented. It can be effect when immune nodes with "P" status persuade their neighber disseminator with the truth. Simulation experiments show that not all nodes in the network will be disseminated and all will lose the trust on the bad information. Exceptionally, the best effection is in BA network with free-scale. The results of this paper can be used for analysis and management of information dissemination on complex networks.

Keywords: *information dissemination, complex network, trust, immune, persuasion*

1. Introduction

Social information can spread rapidly through the different ways [1]. During the process of information dissemination, what influence or determine a person to accept the disseminating informations? How speedy the information dissemination indeed? Can we intervene or control the information dissemination? These are all we interested for research on the information dissemination in the complex networks. The epidemic spreading model [2] provides a method and thinking for the dissemination of information. But there are many different between the epidemic propagation and information dissemination. For example, there are many subjective factors during information dissemination. Because of group psychology, persons will accept the imformation from others. While as sense of justice let us stop harmful information dissemination when we know the truth.

Basing on the epidemic spreading model, IT-SI (Increasing Trust Suspectible-Infected) model is put forward in this paper by introducing trust degree of the individuals in network. It focus on description that people will be increasing their trust degree on the imformation continually and then have increasing infectivity. To prevent the illegal intentions or rumormongers disseminating bad information and rumors, necessary control strategies is needed. The traditional strategies with silent immune attitude have little effect on control of the malicious information dissemination. The paper present a new method, SIP model with "Persuasion" mechanism to control information dissemination. Immune nodes with "P" status persuade their neighber disseminator with the truth. So, the dissemination of bad information can be controlled well. Simulation experiments have done to analyze and manage the information dissemination in complex network

2. IT-SI Model for Information Dissemination

2.1. The Construction and Evoluting Algorithm for IT-SI Model

The infection mechanisms of SI model can be represented by the following formula.

$$S(i) + I(j) \xrightarrow{p} I(i) + I(j) \quad (1)$$

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Here, *p* is defined as infection probability to represent the infectious capacity of the disease. It is a constant according to mean-field theory.

Information dissemination is similar to epidemic spreading. SI model can be use for reference. 'S' is the state for who hasn't known the information, but may be spreaded. 'I' is the state for who has known the information and can transmit to others. *p* is probability for the person in 'I' state transmitting the information to a person in 'S' state. During information dissemination, propagation probability *p*, is not only decided by the value of information itself which equivalent to infectivity of the infectious diseases, but also lie on individual psychological factors. When a person hears of the information, although his state is changed from 'S' to 'I', he don't trust it fully. The trust degree will also affect on the person to send the information or not. The higher the trust degree is, the more willing the individual is to share the information with others. Because of individual psychology, when individuals found each other also known the information, which means a person in 'I' state selects his neighbour also in 'I' state to communicate, they both increase their trust degree of the information. Therefore, in the process of information transmission, with the increasing of 'I' state population, pepole in 'I' status has more chance to be selected as the information receiver. Then they will be increasing their trust degree on the imformation continually. At the same time, the infectivity is enhancing constantly. Accordingly, the Increasing Trust SI (IT-SI) model is established. The definitions are shown as follows.

Definition 1: define States={S, I}, for individual state set in the system. Here 'S' represents a vulnerable status, and 'I' represents infection status.

Definition 2: define information dissemination value $\lambda \in [0,1]$, and information credibility $T_0 \in [0,1]$.

Definition 3: define $Tv,t \in [0,1]$ as the trust degree of the system node *v* with 'I' status at time *t*.

Definition 4: define disseminating rules.

(1) At time *t*, individuals with 'I' status will select a neighbour to transmit the information following the probability *p*, $p= \lambda Tv,t$.

(2) At time *t*, if the individual *v* with 'I' status select the neighbour *u* with 'S' status to transmit the information, individual *u* will change his status from 'S' to 'I', and the trust degree variable $Tu,t+1= T_0$ at $t+1$ moment.

(3) At time *t*, if the individual *v* with 'I' status select the neighbour *u* also with 'I' status to communicate, both of them increase the trust degree variables. $Tu,t+1=1- (1- Tu,t) (1- T_0)$, $Tu,t+1=1- (1- Tu,t) (1- T_0)$.

In the IT-SI model, Nodes exist in two states, 'S' and 'I'. In the beginning, there are SEED nodes with 'I' status in the crowds, and others are with 'S' status. All of the 'I' status nodes in the network disseminate the information according the rules defined in Definition 4. The evoluting algorithm is as follow.

```
Init SEED,N, t=0; N is the total of crowds
Init the state for all of nodes; there are SEED nodes with 'I' status, and N-SEED nodes
with 'S' status.
infection=SEED;
while infection<N
{
for each node v with state='I' at t moment
 if rand < p
   {
select a neighbour u
      if state(u)= 'S'
         state(u)←'I', Tu,t+1←T0,
infection←infection+1;
     else
         Tu,t+1←1- (1- Tu,t) (1- T0),
Tu,t+1←1- (1- Tu,t) (1- T0);
      }
  t=t+1;
}
```

2.2. Evolution of IT-SI Model in Complex Network

ER network is most classical complex network model. It reflects the randomness of the complex network structure. Small world network [3] reflects that the network system has a great size, but there is relatively little distance between any two nodes, such as friend relationship in the real life. NW network model is a typical small world network model. Like Internet, WWW and other network, there is a power-law degree distribution, rather than exponential distribution of random network and small world network. BA network is a scale-free network model. It is the scale-free complex network. This paper will discuss evoluting process of IT-SI model in these cmplex networks by simulation experiment.

On the basis of algorithms of ER model, NW model and BA model [4, 5], three different types of network are simulated. For analying and comparing expediently, the simulation parameters are the same. The total of nodes in the network $N=5000$, the average degree $<k>=10$, the number of the initial infection $SEED=1$.

Assuming $\lambda=1$, $T_0=0.1$, Figure 1 shows the results of the simulation experiments carring out in ER network, NW network and BA network. In order to ensure the correctness of the experimental results, each experiment performed independently 100 times, and the average is calculated for the results.

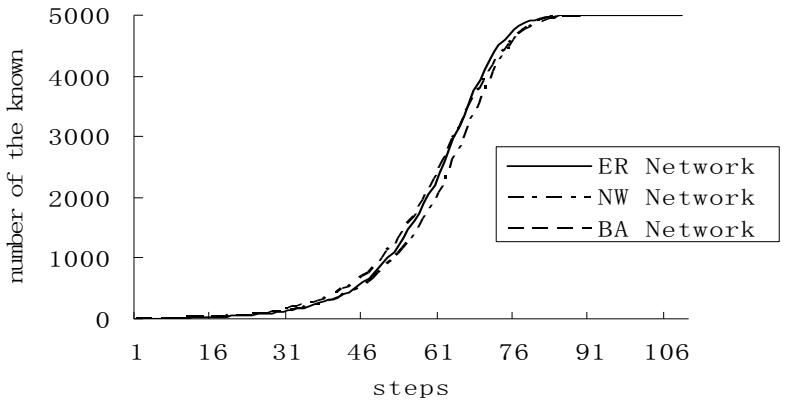

Figure 1. IT-SI Model Evoluting in Complex Networks

We can see from Figure 1 that the information dissemination proceess are same in the three different complex networks. Because only one or two has known information in the begining, the dissemination power is shortage. This time, the information dissemination is in the incubation period, the first stage of information dissemination. as the individuals send the imformation to their neighbors, more people begin to hear of information and transmit. The information dissemination now enters the second stage, occurrence period. During this period, because a few people know the information, a person has insufficient confidence in the information because few people discuss the information with him. So, the trust degree is lower, and the dissemination speed is slower. As more and more people know and spread the information, the information dissemination rapidly enters into the third stage, the outbreak period. The speed is rising sharply until nearly all knowing the information. Last, the information dissemination enters the last stage, stable stage. Almost erveryone in the network has known and trust the imformation fully.In complex networks, from the information arising to the end of information dissemination, the time steps passing over is very limited rarely, In the simulation casesin this paper, it is only about 100 steps. As a comparison, we have performed the same experiment in coupling network, using the same parameters. The results show that more than 5000 steps are needed to transmit the message to the vast majority of people, and enter the stable period of the information dissemination.

The complex network environment are helpful to transfer information, is due to the small world of complex network. ER network, NW network and BA network are all have the characteristic of small world. The short network diameters and average distances facilitate transfer of information.

3. Control Strategy of Information Dissemination

Whether in the reality of social network, or the Internet environment,the rapid spread of information on one hand can make we share information with the fastest speed. But on the other hand, for some illegal intention to spread bad information or rumors, it provides convenience. The dissemination of bad information, and rumors must be controlled, otherwise it will harm to people and society.

3.1. Effect Analysis of the Traditional Immune Strategy

The traditional immune strategies [6, 7] include stochastic immunization, target immunization and acquaintance immunization. In order to test the control effects of these immunization strategies in the information dissemination process, the following experiments is processed. In the three types complex networks, ER model, NW model and BA model, seting up the first 20 nodes for the immune, other parameters same as the second chapter simulation experiment, the IT-SI model is evolutd. During the evolution, if immune node is selected by his neighbor, status and trust degree variable of dissemination node have no change. We can see the experimental results in Figure 2. The x-axis shows the steps during information dissemination.

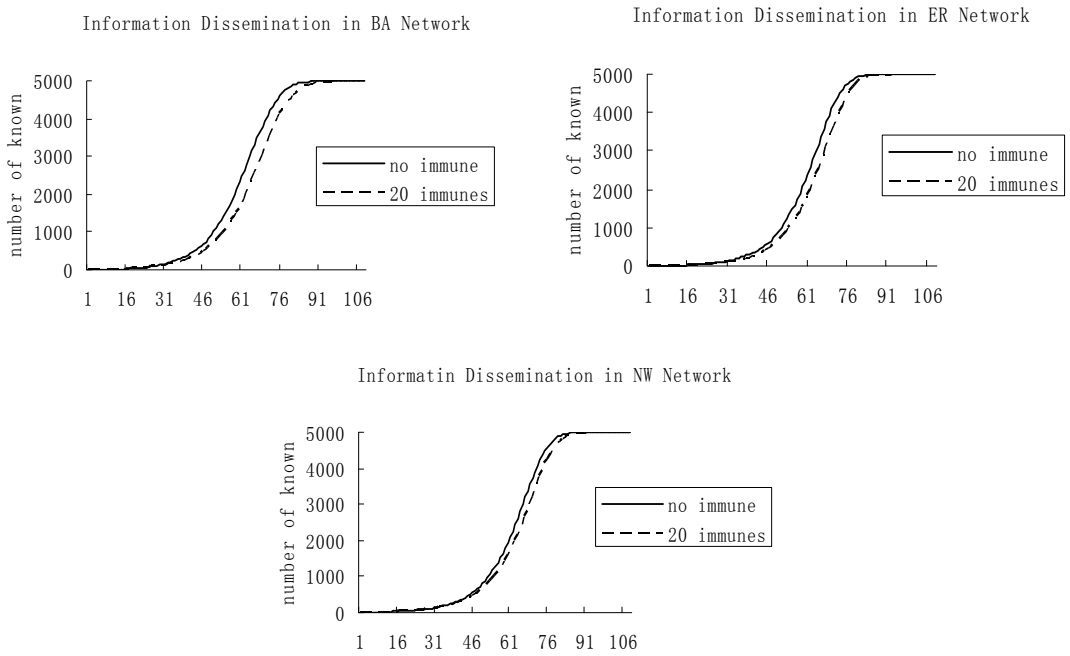

Figure 2. IT-SI Model Evoluting in Complex Networks with Immune

For the ER, NW model, from the mean field theory point of view, to select the first 20 nodes as immune, equivalents to stochastic immunization.To select the first 20 nodes with larger degree as immune in the BA model, equivalents to the target immune. From Figure 2, we can find that traditional immunization strategy can weakly extend information dissemination time steps, but can not change the process and the results. In a short time, every one in the network will know the information. Finally, people accept and believe the bad information.

3.2. SIP Model Building to Control Information Dissemination

The traditional immune node is in a quiescent state in the process of information transmission. He does not participate in the information dissemination and also doesn't interfere with information dissemination. He has almost no influence on the others, and his impact on the whole communication process is very little, almost negligible. So, the traditional immune strategies almost have no effect on controling information dissemination, especially the bad information or rumour disseminationr.communication.

In order to control the information dissemination effectively, we need to endue new responsibility for the traditional immune, to persuade who want to transmit the bad imformation to him to untrust the imformation through telling the truth. Here we call these immunes as persuasion nodes in 'P' status. In the information dissemination, when adverse information is transmitted to persuasion node, persuasion not only do not believe rumors and don't spread rumours like the traditional immunes, and will try to persuade disseminator with the truth. Thus, the disseminator communicators will become the new persuader with 'P' status, no longer spread bad information, and as far as possible to persuade others.

SIP model, is an extension of IT-SI model built through adding new status 'P' for immune nodes. Compared with IT-SI model, revised definitions are shown as follows.

Definition 1' (revised definition of definition 1), define States={S, I, P}, for individual state set in the system. Here 'S' represents a vulnerable status, 'I' represents infection status, and 'P' represents a persuading status.

Definition 4' (revised definition of definition 4): define disseminating rules.

(1) (2) (3) are same as defininition 4.

(4) At time t, if the individual v with 'I' status select the neighbour u also with 'P' status to communicate, the disseminator with 'I' statum will change to 'P' status at *t+1* moment.

The rest of the definitions are same as the IT-SI model.

3.3. Evolution of SIP Model in Complex Network

Using the same parameters, *N=5000*, *<k>=10*, *SEED=1*, the five nodes in the front selected to be with 'P' status, $\lambda=1$,$T_0=0.1$, the simulation experiments are carried out. The process and results are shown in Figure 3.

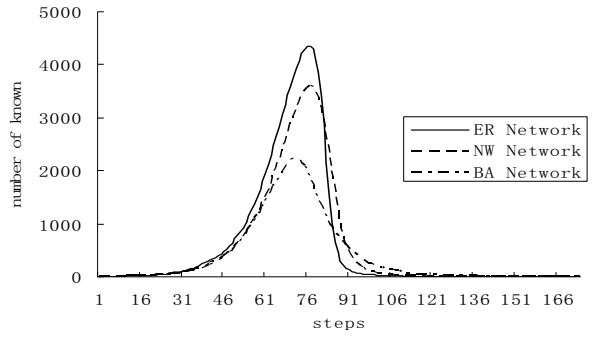

Figure 3. SIP Model Evoluting in Complex Networks

We can see from Figure 3 that adding 'P' status can control harmful information dissemination well in complex networks. Because when the disseminator ('I' node) is exposed to the truth ('P' nodes), he will stop the disseminating behavior and consciously tell the truth to the neighbors who want to disseminate the bad information. His state is change to 'P' status.

Specifically, SIP dissemination control model can be divided into the following stages.

The first stage is incubation period. In this stage, one or two people have known the bad information, and intended to disseminate information.

The second stage is occurrence period. In this stage, few people have known the bad information and disseminate it. Dissemination power is accumulated in the process.

The third stage is outbreak period. In this stage, dissemination power is enough. So, speed of bad information dissemination is rapidly rising. More and more people are involved in the bad information dissemination. Also in this process, many disseminator have more chance to contact to the persuader, the control force is increasing.

The forth stage is inhibitory stage. In this stage, the control forces are power. So, the bad information dissemination is suppressed through persuasion mechanism. Peoples have known the truth, and abort to trust and spread of bad information.

The fifth stage is stable stage. In this stage, no one will trust and spread bad information.

Further analysis can find that the best control effect of SIP model is in BA network. Information dissemination enters the inhibitory stage first. Moreover, in the whole process of information transmission, only less than half are exposed to the bad information. The reason is the free-scale of the BA network. It makes the nodes in network can contact with those with great degrees. When the nodes with 'P' status are selected by those with great degrees, the state of those with great degrees is chaged to 'P'. Furthmore, when those 'P' statum nodes with great degrees is selected by others following higher probability, those 'I' statum nodes change their state to 'P'.

4. Conclusion

This paper is based on the infectious disease model, SI model. Considering the influence of the conformity to the trust degree on information, Increasing Trust SI model is created to describle the process of information dissemination more accurately. Due to the small world characteristic of complex networks, the information can be quickly broken out in the networks and spread every where in the networks. Apllicating this characteristic, illegal intentions and rumormongers often disseminate bad information and rumors with damaging consequences.

Due to the silent immune attitude, the traditional immune strategies have little effect on control of the malicious information dissemination. Then, the paper has put forward SIP model with "Persuasion" mechanism to control information dissemination. During information dissemination, disseminators will be told the truth by persuadors. They would never trust the bad information and then also become new persuadors. So, the dissemination of harmful information is controlled well. Because the scale-free of BA network, persuasion mechanism of SIP model can control harmful information dissemination in a limited range, and eventually makes all disseminators to get rid of the bad information.

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