Computers, Materials & Continua CMC, vol.60, no.3, pp.1015-1027, 2019

Research on Public Opinion Propagation Model in Social Network Based on Blockchain

Gengxin Sun[1, *], Sheng Bin[1], Meng Jiang[2], Ning Cao[3], Zhiyong Zheng[4], Hongyan Zhao[5], Dongbo Wang[6] and Lina Xu[7]

Abstract: With the emergence and development of blockchain technology, a new type of social networks based on blockchain had emerged. In these social networks high quality content creators, filters and propagators can all be reasonably motivated. Due to the transparency and traceability brought by blockchain technology, the public opinion propagation in such social networks presents new characteristics and laws. Based on the theory of network propagation and blockchain, a new public opinion propagation model for this kind of social network based on blockchain technology is proposed in this paper. The model considers the effect of incentive mechanism produced by reasonably quantifying value contribution on the propagation of information in such social networks, and the income-risk matrix under different propagation behaviors is constructed. Furthermore, the transformation process and transfer probability among different states in the propagation model are defined on the basis of income-risk matrix. The model is helpful to break the bottleneck of network public opinion management by using blockchain technology. The propagation of false network public opinion can be contained, and a good ecological environment of network public opinion propagation would be realized.

Keywords: Blockchain, social network, public opinion propagation model, incentive mechanism.

1 Introduction

In recent years, social network services have emerged in large numbers. It has become the main platform for the public to acquire and propagate information and exchange views. In social networks, users no longer passively accept information, but actively provide information and propagate information. Through the active and strong interactive

[1] School of Data Science and Software Engineering, Qingdao University, Qingdao, 266071, China.

[2] School of Electronic and Information, Shandong Modern University, Jinan, 250104, China.

[3] College of Information Engineering, Sanming University, Sanming, 365004, China.

[4] Department of Information Engineering, Fujian College of Water Conservancy and Electric Power, Yongan, 366000, China.

[5] College of Information Engineering, Shandong Yingcai University, Jinan, 250104, China.

[6] College of Technology, Weifang University of Science and Technology, Weifang, 262700, China.

[7] School of Computer Science, University College Dublin, Dublin, Ireland.

[*] Corresponding Author: Gengxin Sun. Email: sungengxin@qdu.edu.cn.

way, the exchange of ideas and the propagation of information are completed. Because of the convenience of information propagation and the cross-platform nature of the main body, the range and degree of impact of information in social networks can be easily amplified in an instant so that a network public opinion emerges. On the basis of rational abstract network public opinion propagation process, constructing network public opinion propagation model helps to better understand the propagation law of network public opinion.

With the emergence and application of blockchain technology, a social networking media platform based on blockchain technology represented by Steemit (steemit.com) emerged. This kind of social network has the characteristics of decentralization of information transmission and irreversible information generation brought by blockchain. In the process of information propagation, a distributed account book is used to establish an information release and propagation tracking mechanism, and a reasonable incentive mechanism is provided for the publisher and the propagator of the information, thereby constructing a new network public opinion propagation ecosystem. In the social network based on blockchain technology, the information forwarding cost is higher, and the public opinion propagation process is transparent. This will make the user release and forward the information more rationally and can limit the spread of false information to a certain extent.

Although the social network based on blockchain can create a more transparent data interaction and propagation environment and subvert the existing network public opinion propagation law, the research on network public opinion propagation model based on blockchain technology is still in its infancy. Swan [Swan (2005)] first studied the information propagation in blockchain and pointed out its application prospects in social networks. Yuan et al. [Yuan and Wang (2016)] elaborated the development and prospect of blockchain technology in the field of social networks. Lin et al. [Lin, Liu, Xiao et al. (2018)] studied the incentive mechanism in blockchain-based information propagation, and proposed an incentive mechanism based on routing mechanism, which greatly improved the efficiency of blockchain information propagation. Chen et al. [Chen, Dong and Sun (2017)] proposed a public opinion-oriented social media text orientation analysis method in the research of private blockchain based on crowdfunding business. Using social network analysis methods, Zhao et al. [Zhao, Wang and Han (2018)] analyzed the characteristics and laws of public opinion information propagation in blockchain networks from the perspective of empirical analysis. Li [Li (2017)] pointed out that blockchain technology can make high-quality content in social networks stand out and build a new network of public opinion.

Through the relevant domestic and international research and analysis, it can be seen that the research on social network public opinion propagation based on blockchain technology has not formed a systematic theoretical system. The research results of the network public opinion propagation model based on blockchain technology are also very few. Therefore, this paper According to the actual impact of blockchain technology on social network public opinion propagation, a public opinion propagation model suitable for social network based on blockchain is proposed.

2 Social network public opinion propagation based on blockchain

Public opinion research began in the social sciences and is one of the main research

contents of social propagation. Under the current intertwined network and real society, network public opinion has been deeply involved in real life and changed the ecological environment of public opinion, so that formed a new network of public opinion. As the main medium of online public opinion propagation, the social network covers all forms of network services with human social core as the core, forming a mass user group that propagates through the Internet, has common interests, and publishes and discusses common interest topics [Boyd and Ellison (2010)]. It has led to a wider spread of online public opinion, affecting more audiences, and more sensational fermentation time, making the control of online public opinion more difficult.

Due to the strong anonymity and diversity of social networks, users can publish and forward information randomly in social networks, which leads to the inaccuracy of information, even rumors, in the process of network information propagation. Therefore, how to make the information propagation in social networks more trans-parent and the information forwarding behavior more standardized is the core problem that the social network public opinion propagation needs to solve. The decentralized, unchangeable, unforgeable, traceable characteristics of blockchain technology [Tapscott and Tapscott (2017)] can solve this problem better.

Steemit is a typical blockchain-based social network that functions like a short book (www.jianshu.com) and is a premium content creation and sharing community that encourages users to create their own work on social networks (An essay, a photo, a video, etc.) to propagate with each other and reward social network participants with Steem tokens. In the social network, the network propagation information produced by the user is stored in the public blockchain steem in an unmodifiable manner, and an incentive mechanism is designed to promote the production and propagation of information.

The first page of the Steemit social network is shown in Fig. 1. The area of the red box, the number on the left is $653.42, which represents how much Steem token the value of this work is. The middle number 506 represents how many people like this work, and the number 155 on the right indicates the number of responses to this work.

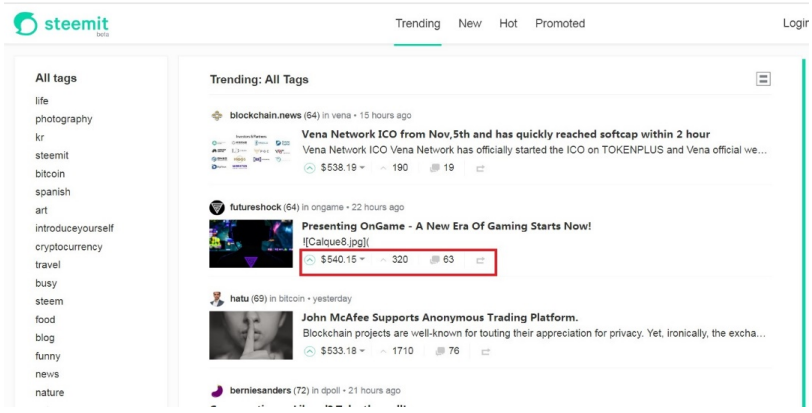

Figure 1: Homepage of Steemit

Several ways to get Steem tokens in this social network are as follows:

1. Publishing high-quality works: The higher the quality of the work, the more praises received, the higher the creator's reward for the Steem token;

2. Spreading high-quality works: The sooner you support the newly published works by means of praise, message, and forwarding, the higher the Steem token rewards received by the propagators;

3. Holding steem power: Similar to equity dividends, you can use "approval/objection" to determine the profit of each work;

4. Buying Steem tokens through an external exchange.

The first three methods are directly related to information propagation in social networks. In order to obtain higher token rewards, users will try to choose high-quality resources when publishing and forwarding relevant information. In addition, each user has a reputation value, which must be gradually increased by posting, commenting, and likes. Moreover, if the resource forwarded or supported by the user proves to be a bad resource, not only will the publisher be deducted the corresponding token and credit value, but the users participating in the forwarding and likes will also be deducted from the corresponding reputation value. Arbitrary forwarding of unverified public opinion information will rarely occur.

Since the Steemit social network is based on the public blockchain steem, one of the features of the blockchain is that the content cannot be tampered with, which makes the information released in the social network cannot be modified at will. In addition, information propagated in social networks is recorded by distributed ledgers. By tracking the books, the propagator can make a basic judgment on the credibility of the information before it is transmitted. Through the distributed ledger, the whole process of information propagation in the social network can be traced, thus achieving the traceability of the information propagation chain.

In the Steemit social network, by analyzing the impact of blockchain technology on information propagation, it can be found that the differences in public opinion propagation between social networks based on blockchain technology and traditional social networks are as follows:

1. The public opinion propagation behavior of users in social networks based on blockchain technology is more rational than users in traditional social net-works, and it only responds to public opinion information that is considered to have reliable credibility;

2. Since the innovative incentive mechanism is introduced in the social network based on the blockchain technology, the users in the social network based on the blockchain technology generally have higher enthusiasm for forwarding the public opinion information than the users in the traditional social network;

3. In the blockchain, miners need to provide computational power for the block-chain network in order to complete the storage of block information. It makes the type of users in the social network based on blockchain technology and the possible propagation status of users in the process of public opinion in-formation propagation are completely different from traditional social net-works.

Therefore, the existing social network public opinion propagation model cannot truly describe the process and law of public opinion propagation in social networks based on blockchain technology, which requires constructing a network public opinion propagation model that is more consistent with blockchain social network.

3 Constructing model

3.1 Information propagation mode in social network based on blockchain technology

In the process of social network information propagation based on blockchain technology, users have the roles of "communicator" and "recipient". The propagation relationship between users must first be authenticated by both parties. Therefore, a social network can be seen as a complex network [Boccaletti, Latora and Moreno et al. (2006); López-Pintado (2008); Kitsak, Gallos and Havlin et al. (2010)] with users as nodes and some relationship between users (friend relationship, relationship, etc.) is edge. "Forwarding" means that when the user receives the information of uncertain authenticity, through objective analysis, the information is propagated along the edge between the nodes to the neighboring nodes in the network, which is shown in Fig. 2.

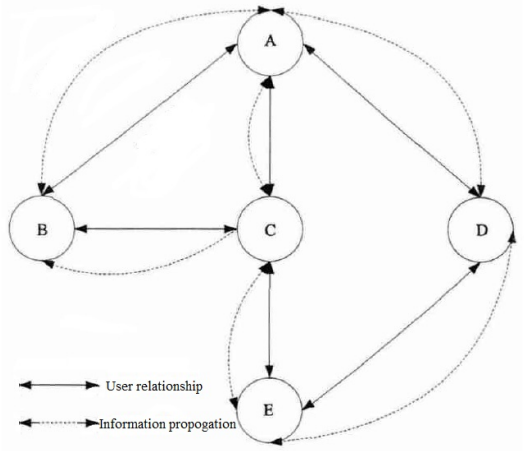

Figure 2: The mode of information propagation in social networks

The inter-user relationship in Fig. 2 is assumed to be a friend relationship. Then, when user A posts a public opinion message, user A becomes the propagator of the public opinion information, and his friends B, C, and D can all obtain the public opinion information, and they all become the recipients of the public opinion information. Assume that user B and D do not forward the public opinion information after objective analysis, then B and D become temporary immunizations of public opinions; after user C has forwarded the public opinion information after objective analysis, C becomes a public opinion disseminator. B and E who are friends of C will get this public opinion information. At this time, user B receives the public opinion information for the second time and will decide whether to forward the public opinion information according to his own analysis, and user E will become the recipient of the public opinion information because of C forwarding.

Because of the technical characteristics of the blockchain, users in social networks based on blockchain technology are generally more enthusiastic about the propagation of information, and can analyze the received information more objectively, and then make their own propagation strategies: forward or not forward. In addition, since the social network based on blockchain technology introduces an incentive mechanism that encourages users to propagate high-quality information, users can obtain more revenue (getting tokens and increasing reputation values) when forwarding high-quality information. When the transmitted information is confirmed to be distorted, the user will also suffer a heavier penalty (loss of reputation value).

A limited rational population [Feng, Zhu and Yang (2017)] is prevalent in social networks, and such people are susceptible to the surrounding population when making their own forwarding decisions. The information propagation incentive mechanism adopted by social net-works based on blockchain technology often allocates more benefits to users who support or forward high-quality resource information, so the same user's propagation strategy for the same public opinion information may change over time. For example, for a public opinion information that a user has previously accepted but not for-warded, as time passes, the information is proved to be a good resource by voting, likes, comments, forwarding, etc. in the social network, when the user receives the information again. In the public opinion information, the user may forward the public opinion information for profit reasons and the influence of the surrounding people. Therefore, in the social network based on blockchain technology, the quality re-sources are more supported and forwarded. The phenomenon that the rich are getting richer [Guo (2014)] is ubiquitous.

Finally, due to the non-modifiability of the blockchain technology, once a user forwards the public opinion information, the forwarding information and related operations have been stored in the distributed ledger and cannot be deleted. There-fore, even if the user no longer propagates the public opinion information all its neighbor nodes can still receive the public opinion information forwarded to it.

3.2 Public opinion propagation model in social network based on blockchain

Based on the SIR model, this paper proposes a revenue-risk matrix under different propagation behaviors. This matrix combines the characteristics of the blockchain technology and considers the impact of the incentive mechanism generated by the reasonable quantitative value contribution on the user's propagation of information. According to the matrix, using evolutionary game theory, adding new state and redefining transition probability based on SIR model, a social network public opinion propagation model based on blockchain technology is constructed.

For the real situation of public opinion propagation in social networks based on blockchain, the nodes in the social network are divided into the following four states: uninformed state (S), informed state (E), forwarding state (I) and immune state (R). The uninformed state means that the user has never received the target public opinion information, that is, the user is in an unknown state of the public opinion information; The informed state indicates that the user has obtained the target public opinion information through the forwarding of other users in the network, but the state in which it has not been converted into its own

propagation strategy; The forwarding state refers to the state in which the user has forwarded the target public opinion information; the immune state refers to the state in which the user has decided to never forward the target public opinion information. The transition process between the four states is shown in Fig. 3.

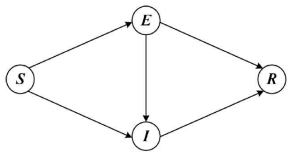

Figure 3: The model of public opinion propagation in social network

It can be seen from Fig. 3 that when an individual in a non-informed state is affected by an individual in a forwarding state, it will be transferred to an informed state or a forwarding state with a certain probability; when an individual in an informed state is affected by a forwarding individual, it may be transferred to the forwarding state with a certain probability, or may be directly transferred to the immune state with a certain probability; In addition, individuals in the forwarding state can also transfer to the immune state with a certain probability. Whether or not the individual has a state transition is closely related to the incentive mechanism used in the social network based on blockchain technology.

The conversion rules between states are described as follows:

Let $N(k,t)$ be the total number of nodes with moderate K in t time, and $S(k,t)$, $E(k,t)$, $I(k,t)$ and $R(k,t)$ respectively represent that the density of uninformed nodes, informed nodes, forwarding nodes, and immunity nodes with a k-degree in the network at time t. That is, the proportion of the above four types of nodes in $N(k, t)$. And $S(k,t)+E(k,t)+I(k,t)+R(k,t) =1$;

When the uninformed node S contacts a forwarding node I, the uninformed node will be transformed into an informed node E with a probability p_{se}, and p_{se} is called an infection probability;

The informed node E is transformed into the forwarding node I by the probability p_{ei}, and p_{ei} is called the forwarding probability of the informed node E to the target public opinion information;

The informed node E is transformed into the immune node R by the probability p_{er}, and p_{er} is called the direct immunity probability of the informed node E to the target public opinion information;

The forwarding node I is transformed into the immune node R by the probability p_{ir}, and then p_{ir} is called the immunity probability of the forwarding node I to the target public opinion information;

The immune state is the final state in the network. That is, the state of the node entering the immune state no longer changes.

According to the above state transition rules, the social network public opinion propagation model based on blockchain can be described by the following differential equations:

$$\begin{cases} \dfrac{dS(k,t)}{dt} = -p_{se}k\theta(t)S(k,t) \\ \dfrac{dE(k,t)}{dt} = p_{se}k\theta(t)S(k,t) - p_{ei}E(k,t) - p_{er}E(k,t) \\ \dfrac{dI(k,t)}{dt} = p_{ei}E(k,t) - p_{ir}I(k,t) \\ \dfrac{dR(k,t)}{dt} = p_{er}E(k,t) + p_{ir}I(k,t) \end{cases} \tag{1}$$

where $\theta(t)$ represents the probability that any random edge in the network is connected to the forwarding individual at time t.

The transition probabilities p_{se}, p_{ei}, p_{er} and p_{ir} between states in this model are determined by the incentive mechanism used by social networks. In order to better explain the incentive mechanism used in the social network based on blockchain technology. The paper constructs a revenue-risk matrix to formalize the influence of other nodes that a node is connected to when making its own propagation strategy. Before constructing the income-risk matrix, first assume that there are rational groups A and B in the social network, and the bounded rational forwarder group C, which is affected by the A and B groups. Groups A and B must guarantee the existence of information forwarding channels. That is, $A \cap B = S \neq \emptyset$, and $C \subset S$.

Based on the above assumptions, the definition of the income-risk matrix is shown in Tab. 1.

Table 1: Income-risk matrix

		Goup B	
		Forward(y)	Not forwarded (1-y)
Goup A	Forward (x)	$(I+(q+1)\Delta I-[R+(q+1)\Delta R]$ $I+(q+1)\Delta I-[R+(q+1)\Delta R])$	$(I+(q+1)k\Delta I-[R+(q+1)k\Delta R], k\Delta I)$
	Not forwarded (1-x)	$(k\Delta I, I+(q+1)k\Delta I-[R+(q+1)k\Delta R])$	(0,0)

The definition of each parameter in the income-risk matrix is shown in Tab. 2.

When the rational crowd forwards the public opinion information, its neighbor node can accept the message. If its neighbor node can also forward the message, it expands the scope of the propagation. If the message is finally confirmed as a good resource, the forwarder will get the basic income *I*. But if this message is a distorted message, the forwarder will be punished, which is the basic risk R. Because there is a connected user between group A and group B, if both A and B choose to forward the public opinion information, both A and B will expand the message propagation range. It will add a part of the additional benefit ΔI. The additional risk ΔR refers to the fact that the public

opinion information is unknown before forwarding. Therefore, when the spread range is expanded, if the public opinion information is finally confirmed to be distorted, the penalty loss will be more than basic income.

Table 2: Parameters of Income-risk matrix

Parameter	Meaning
I	Basic income obtained by forwarding
ΔI	Additional revenue from forwarding
R	Basic risks of forwarding
ΔR	Extra risk from forwarding
q	Proportion of users who choose to forward in the C group
k	Forwarding income increase ratio
x	Probability of group A forwarding sensation information
y	Probability of group B forwarding sensation information

The use of evolutionary game theory can facilitate the calculation of the stability strategy of the matrix.

$$\alpha = I - R + (\Delta I - \Delta R)k(q+1) \tag{2}$$

$$\alpha - \beta = (\Delta I - \Delta R)(1-k)(q+1) \tag{3}$$

$$\alpha - \gamma = (\Delta I - \Delta R)(q+1) + I - R - k\Delta I \tag{4}$$

Therefore, the income stability results under different forwarding conditions as shown in Tab. 3 can be obtained.

Table 3: Stability income results under different conditions

Parameter	Condition
$\alpha > \beta >$	Groups A and B choose to forward
$\alpha > \gamma >$	Groups A and B choose to forward
$\beta > \alpha >$	Group A chooses to forward, group B chooses not to forward
$\beta > \gamma >$	Groups A and B have one party choose to forward, and the other party chooses not to forward.
$\gamma > \alpha >$	Group B chooses to forward, group A chooses not to forward
$\gamma > \beta >$	Groups A and B have one party choose to forward, and the other party chooses not to forward.

4 Experimental analysis

4.1 Experimental dataset

In order to obtain the typical block network-based social network public opinion dissemination sample data, the paper uses the reptile tool to collect the works re-sources of 16 popular labels such as life, food and bitcoin in the Steemit social net-work. A total of 1257 pieces of raw data were collected. It is used as the initial public opinion information, and then collects the publicity information of the forwarder and the liker based on the initial public opinion information to further collect the data of the relevant forwarder, and finally crawls the title, author, time, and bounty in each original public opinion information. Attribute information such as forwarding quantity, number of likes, comment content, user reputation, etc., form the final experimental dataset.

The experimental data set is constructed into a complex network through the for-warding, comment, and praise relationships in the social network. The topology of the network is shown in Fig. 4.

Figure 4: Steemit public opinion information propagation network

The color depth of the nodes in Fig. 4 represents the user's reputation value. The deeper the color, the higher the reputation value of the user. As can be seen in Fig. 4, according to different hobbies and labels, the community structure is more obvious in the process of propagating the public opinion information. The data set under the bitcoin tag is selected separately for analysis, and the obtained network topology is shown in Fig. 5.

The thickness of the edge in Fig. 5 represents the frequency of the spread of public opinion information. As can be seen in Fig. 5, there is no large degree nodes, and the difference between the nodes is not large. It shows that the users who participate in the blockchain public opinion propagation the public opinion information are more average and have less core users.

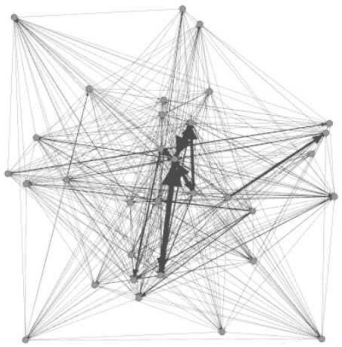

Figure 5: Public opinion information propagation network of bitcoin tag

In order to further explore the differences in the public opinion propagation the public opinion information between social networks based on blockchain technology and traditional social net-works, the topological features of blockchain public opinion propagation networks are analyzed by means of Gephi software. The results show that the network clustering coefficient is 0.001 and the average path length is 2.267, indicating that the network does not have obvious small world characteristics [Watts and Strogatz (1998)]. In addition, the user degree distribution is analyzed, and the user degree distribution fitting power law distribution is found, which indicates that the network has obvious scale-free characteristics [Albert and Barabási (2002)].

4.2 Experimental simulation and analysis

In the paper, the computer simulation experiment of the social network public opinion propagation model based on blockchain is carried out, and the simulation results are analyzed. Compared with the traditional social network public opinion propagation model, the biggest difference of social network public opinion propagation model based on blockchain technology is that users are more affected by the incentive mechanism of the blockchain social network and the surrounding people when determining their own propagation strategies. It is embodied as the forwarding probability p_{ei} from the informed node *E* to the forwarding node *I*.

Fig. 6 shows the trend of the number of forwarding nodes and the number of immune nodes over time when the forwarding probability p_{ei} takes different values.

It can be seen from the curve change of Fig. 6 that before the network reaches the steady state, the larger the value of p_{ei} is, the larger the value of $I(t)$ will be, and the smaller the value of $R(t)$ will be. It is because p_{ei} indicates the probability that the informed node will transition to the forwarding node, and the increase in the p_{ei} value indicates the more the node in the informed state. Affected by incentives and surrounding populations, the probability of forwarding public opinion information increases. In addition, the time when the value of $I(t)$ approaches 0 will increase as the value of p_{ei} increases. It is because as the value of p_{ei} increases, the number of forwarding nodes in the network will also increase, and this will result in a longer time to bring the propagation process to a final stable state.

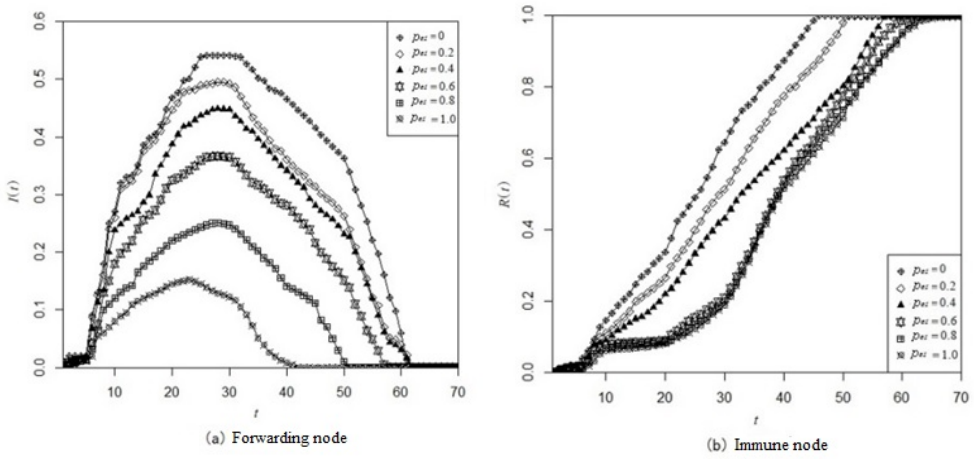

Figure 6: The influence of forwarding probability on the number of propagation node and immune node

5 Conclusion

This paper takes the public opinion propagation model in social networks based on blockchain technology as the research object. Based on the deep analysis of the new characteristics brought by the blockchain technology for social networks, it builds the social network public opinion propagation model based on blockchain technology. Based on the SIR epidemic model, this model redefines the transition probability of each state in the propagation model by introducing new node states and the impact of the unique incentive mechanism of blockchain social network on user's public opinion information propagation. So that this model can truly reflect the law of public opinion propagation in blockchain social networks. The biggest difference between this model and the existing public opinion propagation model is that in order to reflect the incentive mechanism in the blockchain social network, the income-risk matrix is introduced, and the stability strategy of the matrix is calculated by the evolutionary game theory. So that the forwarding probabilities in the model from informed state to forwarding state are redefined. In the paper, the proposed public opinion propagation model is simulated, and the influence of the parameters in the stability strategy of the income-risk matrix on the forwarding probability and the forwarding probability on the public opinion propagation trend in the entire blockchain social network are analyzed. The simulation results show that the blockchain social network users are generally driven by the incentive mechanism to promote the propagation of public opinion information. The blockchain social network will make the high-quality resources prominent, and the spread of distorted public opinion information will be curbed.

Acknowledgement: This work is supported by the Humanity and Social Science Youth foundation of Ministry of Education of China under Grant No. 15YJC860001. This research is also supported by Shandong Provincial Natural Science Foundation, China under Grant No. ZR2017MG011 and Shandong Social Science Research Project under

Grant Nos. 17CHLJ16 and 18BJYJ04. This work is also supported by the Grant of Fujian Middle-aged and Young Teachers' Educational and Scientific Research Projects in 2018, Grant No. JZ180469.

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