Physica A xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Physica A

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

Q1 A novel approach to characterize information radiation in complex networks

Q2 Xiaoyang Wang*, Ying Wang, Lin Zhu, Chao Li

Equipment Management and Safety Engineering College, Air Force Engineering University, Xi'an 710051, China

HIGHLIGHTS

- We introduce a novel model to describe the evolution of the radiation process.
- We analyze the influence of various parameters on safety information radiation.
- The approach overcomes some deficiencies of the commonly used field-theory models.
- Scale-free network has better "radiation explosive power".
- Small-world network has better "radiation staying power".

ARTICLE INFO

Article history:
Received 26 August 2015
Received in revised form 14 November 2015
Available online xxxx

Keywords:
Information radiation
Communication theory
Complex network
Aviation maintenance

ABSTRACT

The traditional research of information dissemination is mostly based on the virus spreading model that the information is being spread by probability, which does not match very well to the reality, because the information that we receive is always more or less than what was sent. In order to quantitatively describe variations in the amount of information during the spreading process, this article proposes a safety information radiation model on the basis of communication theory, combining with relevant theories of complex networks. This model comprehensively considers the various influence factors when safety information radiates in the network, and introduces some concepts from the communication theory perspective, such as the radiation gain function, receiving gain function, information retaining capacity and information second reception capacity, to describe the safety information radiation process between nodes and dynamically investigate the states of network nodes. On a micro level, this article analyzes the influence of various initial conditions and parameters on safety information radiation through the new model simulation. The simulation reveals that this novel approach can reflect the variation of safety information quantity of each node in the complex network, and the scale-free network has better "radiation explosive power", while the small-world network has better "radiation staying power". The results also show that it is efficient to improve the overall performance of network security by selecting nodes with high degrees as the information source, refining and simplifying the information, increasing the information second reception capacity and decreasing the noises. In a word, this article lays the foundation for further research on the interactions of information and energy between internal components within complex systems.

* Corresponding author.
E-mail address: wangxiaoyang1987@163.com (X. Wang).

http://dx.doi.org/10.1016/j.physa.2016.01.076
0378-4371/

Please cite this article in press as: X. Wang, et al., A novel approach to characterize information radiation in complex networks, Physica A (2016), http://dx.doi.org/10.1016/j.physa.2016.01.076

1. Introduction

Complex system science has revealed a novel approach which investigates how interactions between parts of a system give rise to the collective behaviors of a system and how a system reacts and is affected by the environment [1]. The inherent safety of the system structure is decided by the inherent safety and ordering of the component. The ordering of the component is subjected to the interactions of information and energy between microscopic system groups. Safety information radiation refers to the optimal allocation process of transferring and disseminating of safety information including machine information, environmental information and security management that the agent with relatively high degree of safety radiate media to the agent with relatively low degree of safety internal complex systems [2].

The complex network theory is one of the most studied tools for handling such systems, and thus, has attracted much attention in recent years [3–5]. Meanwhile, using complex network to research the spread of the network flows including information, public opinion, virus, risk, etc., has become a hotspot recently [6–9].[1] Among the research that has been done, many spreading models based on the mean field theory are put forward [10–16]. Substituting average effects for individual effect, the mean field theory masks the differences between individuals, but the truth is that different individuals understand the information, even the same information, differently, especially in the spreading process. So, there would be differences in response, when receiving the same information [17]. The information reception is bound up with the simplification of information and the reception capacity of receivers. On the other hand, individuals typically evaluate the quality of the information according to their own values before deciding to pass them on. From a theoretical point of view, this requires construction of models of information dynamics which take into account the contents of the information as well as the role of the individual agent receiving/evaluating/transmitting the contagion. R. Song et al. claim the differential equation model set up by the mean field theory cannot describe the differences of information dissemination between individuals, like invulnerability or vulnerability [18,19]. Using cellular automata and considering the differences of node attack-resisting capability [20], they define the vulnerability function and make the model more universal, their research also shows that the differences of node attack resisting capability have a significant impact on information dissemination behavior. Z. Liu et al. think the mean-field approach cannot show the detailed contagion process, which is important in the control of the epidemic [21]. So, they transform the topological structure of complex network into hierarchical layers and introduce some new characteristic parameters to describe the spreading process in detail. Some researchers [1,22,23] also think it does not match with the reality that the mean-field approach where the role of individual nodes and their interaction with various contagions is approximated in a uniform way. Q. Wu et al. [24] find that a mean-field approximation model can predict the maximal infection level but cannot predict the existence of two critical infection rates through the study. C. Xia et al. [25] consider the case of nonuniform transmission (i.e., the fact that the spreading capabilities of an individual depends on his/her number of contacts) and the situation in which both mechanisms are concurrently active in research.

Taking one real safety information radiation for example, the radiant radiates the safety information to the non-radiate receiver(safety, danger) and information quantity of the destination increase, this information increment vary with node properties, channel environments, and coupling strengths between nodes. But for the source, information quantity would decrease, and this information decrement differs from node to node, similarly. To a certain extent, the complexity of the network structure and the node connections is related to the node properties, which means the features of nodes determine their connectivity to other nodes and the whole network structure. The traditional models have seldom taken into account the node diversity, they measure whether the information has been received through probability or obtained approximately by mean field theory, which does not match very well with the reality. If there is information transmission between nodes, the information increment of the destination no matter how much must exist, therefore the information dissemination cannot simplified to a probability problem so easily.

In order to quantitatively calculate variations in the amount of information during the spreading process, this article describes a safety information radiation model using communication theory, which overcomes the deficiencies of mean field theory. Therefore, in order to fully consider individual differences in radiation ability and receiving capability for safety information, information affected by noise in the channel and other factors, we introduce some parameters and concepts including radiation gain function, receiving gain function, information retaining capacity and information second reception capacity from the perspective of communication theory to analyze the process of safety information radiation in complex networks. We proposed a safety information radiation approach using communication theory, and used this model to analyze each factor in the complex networks of different topologies, and studied the effects of safety information radiation on the networks.

The rest of this paper is organized as follows. Section 2 introduces the network model as the base of the analysis. Section 3 explores a novel approach to characterize safety information radiation and the process. In Section 4, some parameters and concepts are analyzed by simulation. Finally, some concluding remarks are drawn in Section 5.

2. Network model

Take aviation maintenance for instance. Aviation maintenance is a complicated systematic process, in which the obtaining of safety information affects the aviation maintenance quality that directly determines flight safety. Thus, safety

[1] Reviewer #2 comment 2.

Please cite this article in press as: X. Wang, et al., A novel approach to characterize information radiation in complex networks, Physica A (2016), http://dx.doi.org/10.1016/j.physa.2016.01.076