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Dynamic Model for the Prediction of Load Distribution and the Fault Diffusion through a Network

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Abstract

In network science, one or several nodes shocked can trigger lager cascades through faults. Most of these faults relate to the load and capacity of node belonged to a network. According to the queue theory, each node could be seen as a queue model. After analysing the couple relationship among the nodes, a queue model can be improved by building evolution equation about the speed of costumer arriving λ to predict the load. Then we calculate the probability of a network fault. An ordinary differential equation groups (ODE) about the fault spreading can be built whose coefficient equal to the probability of fault. After simulating and analysing the phase trajectory, the ODE model can give a great description of the fault spreading evolution. This can provide a method to check out whether a network is robustness for a kind of cascading failures or whether there are efficient ways to control the influence of cascade failures. After simulating, we conclude that it is useless to repair the fault nodes and put them bake to the network after the cascading failure happened.

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Keywords: network fault, load, queue theory, ordinary differential equation groups

1. Introduction

Network science is penetrated into many fields such as mathematical subject, life science and communication disciplines [1]. Since the scale-free network model was build last century, the researches about the network science, which includes the network fault, stability and dynamic action, have been being an important area [2]. There are a lot researches about the network fault in different environments. In recent researches, there are many achievements about this topic. The method to research the cascading failures in interdependent network is that coupling different model for different network together [3]. The research about cascading failure in directed complex network gives two novel network attack strategies to find that whether a network is stable [4]. The research about network dynamic action is one of the important parts in research the complex network. The models for American power system have introduced a model with dynamic action both of the lines and the nodes [5]. All of the researches are based on the

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model for describing the cascading failures and the dynamic evolution. The capacity-load model describes the problem directly [6]. In order to express the couple relation through the network, researcher build the model couple map lattices (CML) [7].

The model existing now can describe the network cascading fault. However, they are all concentrate more on the dynamic evolution for the single node. And for the network stable study [8], the model about the node is more complex to these researches. The research about message spreading in network provided the ordinary differential equation model for the whole network [9, 10]. And the advantage about the ordinary differential dynamic model is it can provide the final state for the whole net evolution. And queue theory is an classical model for researching the load and buffer for network unit. In research about the bandwidth allocation algorithm for wired-wireless [11], the queue theory model M/M/1 is still a great tool about it. Queue theory provides a lot of models to research the state of each node in a network.

This paper has combined the advantage about the queue model and ordinary model to build a system to prediction the load of each node and describing fault diffusion evolution. It will give a great help for the study about the network stable. This model can be used to analyzing whether a network is robustness for a kind of cascading failures or whether there are efficient ways to control the influence of cascade failures

2. Model for one node

There are many failures in network relate to the load of each node. Such as the computer network, a huge number of the massage data packets will make the network congest. And if the load exceeds the capacity of one node, it would make the node fault even make the whole network break. For each node, the model to describe the state of the node can be build based on the queue theory. First, the flow of data packets coming can be seen as the flow of customer coming with the interval time $1/\lambda$. Then the procession of data packets leaving can be seen as the flow of customer be served with the serving time $1/\mu$. Finally, the number of data packets coming at same time is a random variable number K .

2.1. Model based on $M^{[K]}/M/1$

Each node in a network can be seen as a queue model. The state change of each node is a dynamic process, and it has a great relationship with another node in the network. In order to describe the process, a model will be made under the condition that the relationship with another node only be reflected by the average speed of data packets arrive $\lambda(t)$. Note the load of the i[th] node at time of t as $Lo_i(t)$. This part tries to find the probability $p_n(t)$ of the $Lo_i(t)$ equal different nature numbers.

$$p_n(t) = P\{Lo_i(t) = n\} \tag{1}$$

Assuming the number of customer arriving at same time is satisfied with the binomial distribution, because the data packets are transported through the physic channel. The C_k represents that the probability of the number equal to *k*. The d_i represents that the degree of the i[th] node.

$$C_k = P\{number = k\} = \binom{d_i}{k} \frac{1}{d_i}^{k} (1-\frac{1}{d_i})^{(d_i-k)} \tag{2}$$