Research on Optimization Algorithm for Knapsack Problem of Complex Network Based on Complex Network Evolution

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Abstract. In order to verify the correctness and validity of the complex networks function evaluation algorithm based on node efficiency, we did a simulation experiment, simply use the topology robustness to assess the robustness of the real network is not enough, but also need to consider node load. By increasing the resources of the information processing nodes to improve the reliability of the actual network system; to measure the actual network system functionality robustness, should use conditions of maintaining the normal function of system to restrain. Under conditions of maintaining normal function, scale-free network in response to a deliberate attack is very fragile, but has a strong fault tolerance to random attack; when a node hit is smaller, different ways of attack has little effect on random networks, and there is same classic conclusion with complex network robustness study. The simulation results show that: the assessment of this algorithm which considers the complex network functionality robust of node load is feasible and effective, and for large complex networks, can get a good computing power.

Introduction

There are many complex systems or existing with the form of complex networks the network can be converted into a complex network in real world, such as the personal relationships in social system, collaborative network of scientists and spread net of epidemics, neuronal network in ecosystem, gene regulation network and protein interaction network, telephone network in IT systems, Internet, the World Wide Web and so on. The complex networks generally exist some basic statistical properties, such as the “small world effect” reflecting the length of short path and the characteristics of the high clustering coefficient; the nodes reflecting the complex network obeys the ‘non -standard degree characteristics’ of the distribution of the power rate; Also the description complex network generally exist the characteristics of ‘the characteristics of community structure’ of ‘closely connected nodes within the same community, sparse connected nodes between different communities’ [1-3].

Functional Robustness Assessment Model

The robustness of the network we study is the network is attacked by outside world or face the random failures itself, the ability that complex network system can maintain its function. In this paper, the complex network function robust assessment model considers the network topology node connectivity and the load of node to determine the probability of node failure by the change of node load, then to achieve the aim the assessment of the robustness of the network function. The concept of node load in this article is proposed from the actual network resource distribution process, and it is the abstract representation of the load of node itself, it is characterized by a node to maintain the existing functionality. If the node load is greater, indicating that the more severe the node resource consumption, and the ability to maintain existing functionality is weaker.

For information transmission on network, if the distance between node pair is larger, but need to maintain the integrity of the information transmission, so the resource consumption information transmission between the nodes is less; if the resource of node information processing is limited, then the loads it bear is larger. Due to network efficiency characterize the average closeness of nodes in the network, so the network efficiency to some extent reflects the load of the entire network. If the network efficiency is higher, indicating that the distance between nodes pairs is shorter, and the network information flow more easily, and information transmission network load is smaller.

Since the average value of all nodes efficient in the network is network efficiency w, thus the efficiency of the node also reflects the sustainable load on the node. To the node whose resources for the information processing is fixed, if its efficiency is higher, it means that it is closer to the other nodes on network, and the flow of information is easier, the fewer resources consumed by the information transmission, and the smaller load imposed on the nodes. So, in this paper, we use node efficiency to characterize the load of node LD, and define the load node k as follows:

$$LD_k = \exp(-I_k) \quad (1)$$

The communication network shown in Figure 1, there are four communication paths exists between node v_1 and v_5. When v_1 is invalid, if v_2 and v_5 have sufficient resources to let them follow the path of $v_2 - v_3 - v_4 - v_5$ to communicate, then v_2 and v_5 will not fail, and the entire network can maintain its existing capabilities. Therefore, for the node, as long as it has a certain amount of resources to maintain its existing capabilities, it can withstand a certain load. This article defines the load of nodes in the network as the tolerance of the load B.

For the general actual communication networks, because during the network formation process, the resources of each node in information processing is fixed, and the resource which can be used in information transmission process is the same, it lends to the loads they can bear are the same, both are B. Therefore, we use the same a to characterize tolerate a load of network nodes, and is defined as

$$B = \alpha \times \max(LD_k, k-1, \cdots, n) \quad (2)$$

In the form, $a \geq 1$ is the tolerance factor of the load node.

In an actual system, some of the overloaded nodes are not invalid immediately, because people will take some measures to increase the capacity of the node, and remit the node load to improve the overall reliability of the network, e.g., the Dynamic Routing Policy in communication network. Thus, the failure of any node in the network has a threshold. Due to the fixed network node information processing resources, lead to the same node failure threshold, which is defined as the node load limit

$$B_\infty = \beta \times C \quad (3)$$

In the formula, $\partial \geq 1$ is the factor of limit load.

According to the node limit load and load tolerance, we can define the failure probability w_k of node k as follows:

$$w_k = \begin{cases} 0, LD_k < C \\ \dfrac{LD_k - C}{C_\infty - C}, C < LD_k < C_\infty \\ 1, LD_k > C_\infty \end{cases} \quad (4)$$

From equation (4) we can see: when $\partial \to \beta$, $B \to \infty$, each node has sufficient resources to maintain existing functionality, and is not affected by changes of topology in the network, equal to only study the topology robustness of the network; When ∂ is fixed and $B \to \infty$, it means the extreme load of each node is infinite great, and the failure of overloaded node is not entirely dependent on the load of node, but with a certain probability to maintain existing functionality.

When the network is hit in a certain way, the failed node will lead to changes in the pattern of transmission of information and loads of other nodes, once the load of node exceeds the limit load, it will cause the node failure, and in turn affect its load of other nodes. If the network is hit, and the failed node is less, it indicates the ability to maintain the normal operation of the network is stronger.

Therefore, this article measures the functions robust of network via the number of failed node, and gives its normalized expression

$$f = \frac{\sum_{i=1}^{Num} f_i}{Num \times n} \quad (5)$$

In the formula, n is the number of nodes in the network, Num indicates the number of the network's hit, f_i represents the number of failure nodes caused by the i hit. Every fight is not only limited to one node fails; it can contain multiple failure modes.

Experimental Results

Assume the scale-free communication network and random communication network with the number of nodes are 512 and the number of sides is 1504.

In order to analyze the efficiency of the algorithm, use of the optimization algorithm to run MATLAB programs on the Intel Core 2 Duad 2.86 GHz computer, and assess the functional robustness for the different sizes and small-world network whose weight side is 1 (each node is connected to an adjacent six nodes, the probability of side reconnection is 0.3).

For simple communication network shown in Figure 1, the paper treats network connectivity and maximum connectivity subnet as indicator, when the network assesses topology robustness and functional robustness while k_1, k_1 and k_2 are both failure, the assessment result is shown in Table 1 (multiple emulation average).

Table 1. The result of simple communication network robustness assessment

evaluation index	failure node	k_1	k_1, k_2
topology robustness	network connectivity	connected	unconnected
	scale of Max connected subnet	18	14
function robustness	network connectivity	unconnected	unconnected
	scale of Max connected subnet	15	0
function robustness	network connectivity	connected	unconnected
	scale of Max connected subnet	18	14

As can be seen from Table 1, when $\partial = \infty$, the result of network function robustness is consistent with the topology robustness assessment result; When $\partial = 1, \beta = 1.6$, the evaluation results of network function robustness is different from the robustness of the topology. Analyze the reason, it is due to the assessment of network function robustness considers the tolerated load of communication network node. Once node overload, it will also lead to the destruction of network connectivity and reducing the size of the largest connected subnet, such as edge node k_5, k_6, k_7 overload. We can see, simply use the topology robustness to assess the robustness of actual network is one-sided, only overall consider the network topology, the capacity of the node, and the sustainable load to make the assessment of network robustness is more accurate.

About the study of complex networks robustness, generally consider that in the random attack, scale-free networks have a stronger fault tolerance than random network; but in a deliberate attack, scale-free network seems extremely fragile, use mentioned method in this article to assess the robustness. After simulation (average of multiple sampling), the assessment results of function robustness about random communication network and non-standard communication network are shown in Figures1- 2.

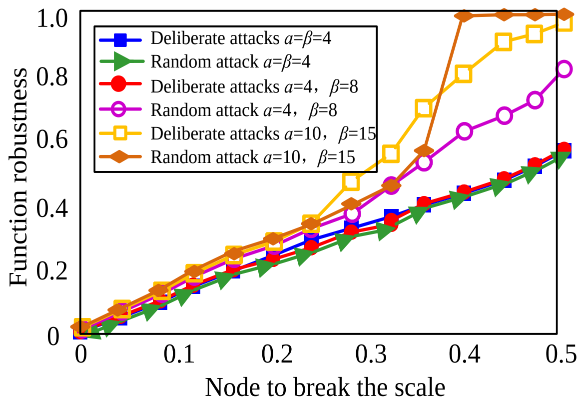

Figure1. Schematic of Functionality Robust of Random Communication Network

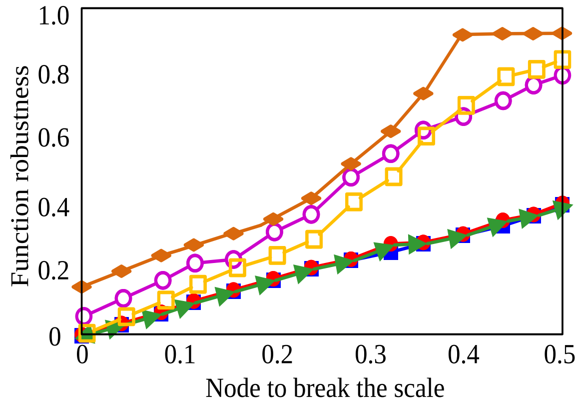

Figure2. Schematic of Functionality Robust of Scale-Free Communication Network

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