Complex Network Function Evaluation Algorithm Based on Node Efficiency

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Abstract: The current complex network evaluation model ignores the global influence, so this paper proposes complex network function evaluation algorithm based on node efficiency. The algorithm overall consider the global influence of node failure, and use the efficiency of the node on network to define the load of each node, Limit load and failure model, with the rate of striking the ultimate failure nodes on network to measure the functionality of the network, the result of robustness experiment proofs: the algorithm is suitable for assessing the robustness of large-scale and small-world network function, the complexity of algorithm time is O(n2).

Keywords: Entropy; Traffic load; Load tolerance factor; Node

1. 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].
Complex network is the abstract of the complex systems, which exit everywhere; many real systems can use abstract as the network model for researching. Complex network researches the core issue that is the relationship between the structure of complex system and the functions. Therefore the function of optimizing the network structure and improving the system has attracted the attention of many scholars in the field of complex networks. On the current research of complex network optimization, different scholars have different needs for different networks and the optimization objectives are not the same [4-5]. Some scholars have focused on improving network robustness. Jing WP et al proposed topology optimization method in wireless sensor network based on Kleinberg model; through the optimization fault tolerance and reliability of the network can be significantly improved [6-8]; Fan W et al through the discovery and improvement of the existing topologies key nodes in complex network, the connectivity and robustness of P2P network are improved [9-11]. Some scholars have focused on improving the network topology features: Wang LF studied the network edge reconnection algorithm; through the reconnection of the edges the synchronism of the network is improved; Ouveysi I et al proposed a LCM-WP ways optimizing fiber optic network from the current research situation and other fiber-optic network in order to reduce the network traffic flow and congestion and optimize the robustness of network, by considering the network topology optimization and survival strategies [14-15]. Many scholars only focus on the purposes of complex network optimization, while the need cost of network optimization is ignored.

2. Theoretical Basis of Complex Network

2.1. Introduce the question

The current methods of studying complex network robustness include the method which based on the shortest path of nodes, and the largest connected subnets scale of network, and network connectivity, etc., but they are based on the research of network topology, but ignored the robustness of the network functions, since the operation of actual network system is not only affected by the topology, but also constraints by the capacity of node itself, e.g., the information transmission on the communication network needs to consider the traffic load information of each node; traffic congestion in transport network need to consider evacuation traffic capacity of the transportation hub. Once node information transmission on communication network is overloaded or traffic flow is over the transport hub of evacuation capacity on traffic network, it will also lead to the collapse of the entire network. Refer to the simple communication network shown in Figure 1 (the right side of the adjacent nodes are l), if the node: 1 is failure, it will make the traffic load which connect subnet A and B superimposed on 4v, once 4v is overloaded, the connectivity of the communication network will be destroyed.

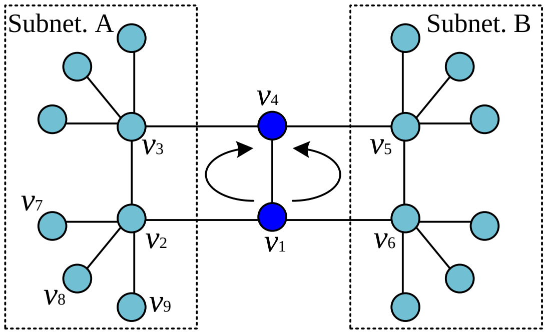

Figure 1. Schematic about distribution of Simple communication network information flow

3. Functional Robustness Assessment Model and Algorithm

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

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

4. Simulation Experiment and Analysis

4.1. Experiment environment and setup

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).

4.2. Result analysis

1) Effectiveness Analysis of Model

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 Figures 2 and Figure 3.

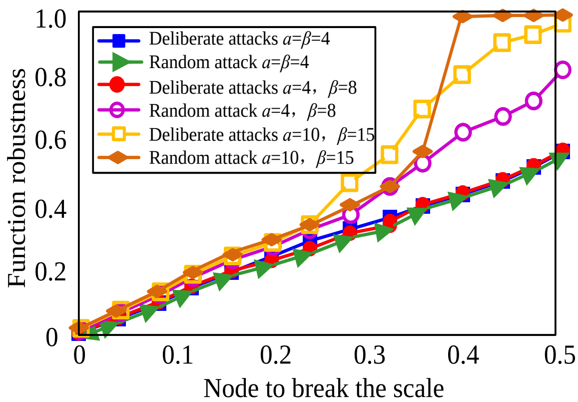

Figure 2. Schematic of functionality robust of random communication network

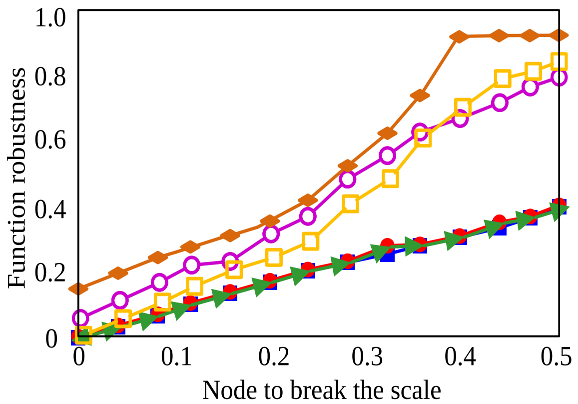

Figure 3. Schematic of functionality robust of scale-Free communication network

As can be seen from Figures 2 and Figure 3, with the increase of tolerance factor and limit factor of the load of network node, the function robustness of the communication network gradually increased. When $\partial = \infty$, the curve of function robustness of communication network is a straight line whose slope is 1, indicating that there is no communication network as a result of overload function failure node, except the hit node, other nodes can maintain its existing communication function, then the function robustness of the communication network is the strongest. We can see, to the actual network system of different topology, in order to increase reliability, reduce the number of function-failure node caused by overload, we can add a node of the information processing resources to increase the capacity of the node, then reduce the failure probability of node function, and let the network has a strong functional robustness.

When the value of ∂ and β is certain, on the whole: scale-free communication network in response to a deliberate attack on its functional robustness is low , but has strong tolerance on random attack; but different ways of attacking random communication has little effect on the network, which is consistent with the classic conclusion of assessment of the robustness of the network, it illustrates the effectiveness of this method, however, the assessment of considering the function robust of complex communications network of the load node, you should use the actual maintain the normal function of the communication system in response to a different mode of attack under constraint. For example: if there is 12% node on communication network is failed, it will make the network collapse, when the size of node is more than 12%, the conclusion of complex network robustness assessment is not true, because in this case the impact of random attacks and deliberate attacks on the communications network is the same, so if the actual network system maintains normal function , scale-free network in response to a deliberate attack is very fragile, However, has a strong tolerance by random attack, which is shown in Figure 3; when the scale of node attack is small, attack in different ways has small influence on random networks, when the size exceeds a predetermined threshold value, deliberate attacks on random network is also very fragile, it is shown in Figure 2 .

2) Algorithm Efficiency Analysis

In the current study on complex network robustness, the reason why scholars consider only local effects of node failures while ignoring its global impact is due to complexity time if consider the robustness assessment algorithm of global information network, for large-scale network, it is not apply, so this paper proposes the robustness of complex networks function optimization algorithm.

Assume $\partial = 3$, $\beta = 8$, the running time (the average of several sampling) shown in Figure 4.

As can be seen from Figure 4, the assessment time of optimized algorithm is no more than 104s on small-world network features robust whose number of nodes is 1000, and the scale of deliberate attacks is 20%, and with the size of the node hit is reduced, its computing power is better, it shows that the proposed algorithm is effective. Because the actual system is mostly has small-world characteristic, so use this method for the assessment of large-scale and small-world function robustness network can obtain ideal computing power.

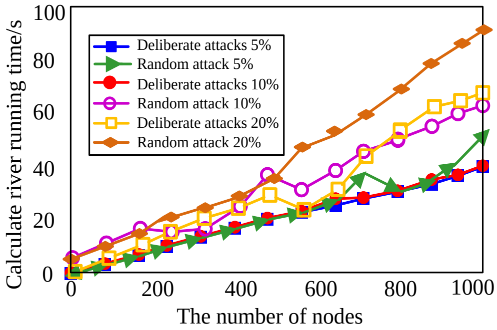

Figure 4. Execution efficiency charts of different size and small world network algorithm

3) The Convergence Rate of Algorithm

Use traditional algorithms for complex network assessment and use our algorithm for security situation assessment of complex network, and the obtained experimental results can be described by Figure 5.

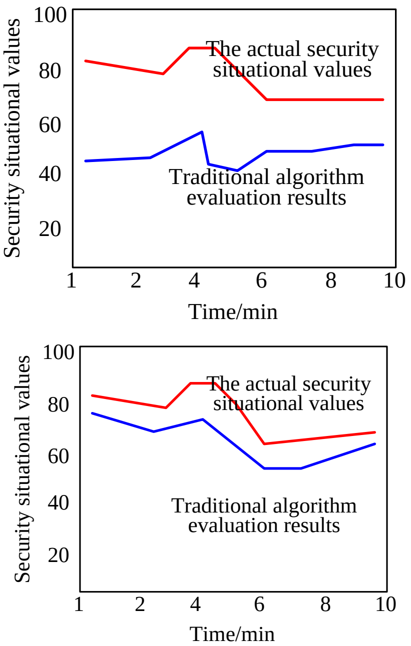

Figure 5. Comparisons about assessment of our algorithm and traditional algorithm

We can know from the above experimental results that the evaluation curve we obtained by using our algorithm for complex network assessment, is closer to the real complex network. It represents that in the process of assessment of complex network, our algorithm has better performance. During the process of assessing complex network by using different algorithms, the convergence rate of evaluation result we obtained can be described by Figure 6. According to the comparing result of convergence rate of different algorithms, we can be informed that the convergence rate of our algorithm is faster, greatly reduces the learning time, thereby improving the accuracy of the assessment of complex network.

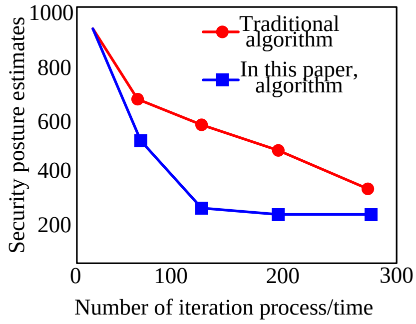

Figure 6. Comparisons about convergence rates of different algorithms

5. Conclusion

For today's complex network robustness evaluation model only consider the robustness of the network topology and the defect of local effect of the failed node, so this paper proposes complex network function evaluation algorithm based on node efficiency. The algorithm overall consider the global influence of node failure, and use the efficiency of the node on network to define the load of each node, Limit load and failure model, with the rate of striking the ultimate failure nodes on network to measure the functionality of the network, the result of robustness experiment proofs: the algorithm is suitable for assessing the robustness of large-scale and small-world network function, the complexity of algorithm time is O (n2).

References

[1] Andrew R,Peters G P, Lennox J. Approximation and regional aggregation in multi-regional input-output analysis for national carbon footprint accounting . Economic Systems Research, 2009, 21 (3): 311-335.

[2] Boyd J P,Fitzgerald W J,Mahutga M C,Smith D A. Computing continuous core/periphery structures for social relations data with MINRES/SVD, Social Networks, 2010, 32 (2): 125-137.

[3] Dietzenbacher E. More on Multipliers. Journal of Regional Science, 2005, 45 (2): 421-426,

[4] Holub H W,Schnabl H. Qualitative input-output analysis and structural information. Economic Modelling, 2012, 2(1): 67-73.

[5] Holub H W? Tappeiner G. A general qualitative technique for the comparison of economic structures. Quality & Quantity, 2010, 22 (3): 293-310.

[6] Kranich J. Agglomeration, vertical specialization, and the strength of industrial linkages. Papers in Regional Science, 2011, 90 (1): 159-178.

[7] Muhammad J. Mirza, Nadeem Anjum. Association of Moving Objects Across Visual Sensor Networks. Journal of Multimedia, Vol 7, No 1 (2012) pp. 2-8

[8] Phakpoom T. Clustering and Industrial Development: Evidence from Thailand. Nagoya University, 2011.

[9] Kwak S J,Yoo S H,Chang J I. The role of the maritime industry in the Korean national economy: an input-output analysis. Marine Policy, 2011, 29(4): 371-383.

[10] Labaj M. Qualitative input-output analysis and national innovation system in Slovakia. International Journal of Transitions and Innovation Systems, 2011, 1 (2): 105-116.

[11] Lahr M L,Mesnard L D. Biproportional Techniques in Input-Output Analysis: Table Updating and Structural Analysis. Economic Systems Research, 2009, 16 (2): 115-134.