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Complex Information Network of Elastic Evaluation and Optimization Methods Study*

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Abstract: Due to complex network environment under the random fault and malicious attack may be caused by network in the node or link fault and then the network service of availability cause obvious damage, design and to cope with network failure of elastic network topology can extend network life save network cost so put forward the kind of based on iterative calculation of heuristic algorithm optimization Network Topology, the given figure add link improve network of average efficiency function improve network elastic. Will the algorithm3A complex network topology and compare the algorithm of benefit. By the random fault and based on center of attack test and evaluation original figure and improve figure of network elastic. And Map Theory of Some Elastic optimization algorithm the contrast simulation results show that in the study of elastic quantitative index in the proposed of heuristic algorithm can optimization Network Topology, compared in other of improved algorithm coping with random fault and center sexual assault more has elastic.

Keywords: Figure robust of; Map; Network elastic; random fault; malicious attack; Network Topology

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1. Introduction

Computer network application in support all kinds of service on the play the more and more key of role. In fact these application has become people daily life of part. Hospital, enterprise, school, Government of daily operation more and more rely on in computer network service. These public available of network service not only easy to the earthquake, hurricane, tsunami and other natural disaster of influence and at any time will happen various fault status and face some network attack, the normal of operation and service interrupt. Network elastic[1-3]Refers to the is network in to deal with many kinds of fault and challenges. provide and maintain can accept level in the service and normal operation of ability. So construction has good elastic of network topology for to deal with challenges and provide can accept level of service can extend network life, save network cost.

General network especially is global Internet have become business and global economic of daily operation of necessary content. So network interrupt of consequences[4]Also become more and more serious. Now widely think current of many reality network don't have enough of elastic need corresponding of research, development and engineering project to improve the basic facilities network and service network[5-7/]Of elastic. For elastic network structure of Research,KumarEt al[8]From complex network topology of angle proposed a kindDLAModel Construction elastic supply network and analysis the proposed of network construction model the structure of network topology in coping with random fault and malicious attacks of elastic Of Course Network Construction Process don't always built from scratch, so can't Solution

The for existing network of elastic optimization problem at the same time, the model only consider the node the most generous this a constraint far not in reality network of construction process. Li Yun Hebei Province *et al*[9]Consider congestion cause of Network Fault on network node and link of importance evaluation based on network of adjacency matrix construction in degree-constrained to minimize the average distance of optimization Network, improve Network of CAN survivability. However compared in construction elastic network also have a large number of working in network topology of optimization improve existing network of topology make its elastic to deal with various challenges and fault. For real of Service Provider backbone network topology suchSprint,AT&T,G, ANT2And Network Topology[10]Of study comprehensive compare the topology of structure characteristics such as average node degree, clustering coefficient, average Shortest Path, radius and diameter and. Compared in characterization network connectivity and robust of these classic of graph theory Index[11]Map Theory measurement standard is figure of robust of index of another subclass research figure of structure characteristics and related matrix of eigenvalue and characteristics vector between the relationship. Some the main can be used for measurement remove node or link after figure of robust of such as algebra connectivity[12], Spectrum gap[11], Natural connectivity[13], Right spectrum[14], Network key[15].AlenaziAndSterbenz[11]Proposed center sexual assault under3A network elastic measure "with Classic Graph Theory index and map on the standard measurement random fault and malicious attack. The network elastic to basic figure and random figure for topology data set, "With Nonlinear related compare the index prediction attack. Network elastic of accuracy.

This paper study of Figure robust of index for network of average efficiency function[16]. The Network Applied random fault and center sexual assault measurement network of flow robust of with the index means that every time attack. reliable flow of availability. Every time node attack. of flow robust of as an network of elastic measure. This paper put forward a kind of iterative algorithm optimization network of connectivity by the given figure add link set to maximize network of average efficiency function improve network elastic. Will the algorithm3Network topology and compare the efficiency of the algorithm. Test and evaluate the original graph and improve the network resilience of the graph by adopting random failures and centrality-based attacks. The main work of this paper is as follows: This paper proposes an optimization algorithm based on the network average efficiency, which is a robustness index to improve the given graph;

This algorithm is used to generate corresponding improvement graphs for complex networks. The network elasticity under Random failures and central attacks is evaluated by stream robustness function.

2. Background and related work2.1Graph mind Measurement

Given GraphG=(V,E), Node SetV,Edge setE.The centrality indicator indicates the importance of the node or link in the graph. Due to the importance of nodes or links in different applications, some indicators can be used as indicators to determine the central node based on the given application.

Node degree centrality$C_D(V)$The number of links defined as the node's association can be seen as the importance of the node's connection. Node degree is a local centrality indicator because it only relies on locally connected links.

Number. Average node degree is represented$C_D(V)$. NodeI,JThe shortest

PathD_{IJ}The path with the smallest number of hops between the connecting points. Average shortest

Path LengthDMeasure the average number of hops on the network. Some common graph metrics such as betweenness, radius, and diameter provide statistics for the shortest path between all pairs of nodes. Betweenness is a centrality metric that can be used for nodes and links. Node betweenness$C_B(V)$Pass through NodeVThe number of shortest paths, while the edge betweenness$C_B(L)$Defined as a passing LinkLThe most

Number of short paths. The global significance of betweenness is that betweenness reflectsThe overall structure of the graph. Node tightness$C_C(V)$Is the

Measurement NodeVCentrality indicator of average distance to other nodes. Clustering co efficient CC(V)Measure NodeV The degree of total connectivity of neighboring points.

2.2 Related map theory knowledge

Some existing studies are used to quantify the robustness of malicious attacks and random failures[3]. Based on the proposed robustness index and

This paper introduces the formulaic representation of each index and the accuracy of network resilience under the central attack.[11]Related work. Graph Theory studies the relationship between the structural characteristics of graphs and the eigenvalues and eigenvectors of the adjacency matrix, correlation matrix, Laplacian Matrix and normalized Laplacian Matrix of graphs.[17].

Given GraphG=(V,E), Node SetV,Edge setE,Number of nodesN,Number of EdgesK.A=$(A_{IJ})_{N*N}$For chartGThe adjacency matrix where:

EigenvalueMuFor characteristics PolynomialDet(A-MuI)= 0Of root.{Mu_{12},...,Mu_N}For adjacency matrix of eigenvalue collection elements was increasing arrangement. Spectrum gap definitionMu=Mu_N-Mu_{N-1}For adjacency matrix of maximum eigenvalue and the second largest eigenvalue between of poor is measure malicious attack the following figure robust of a main[11]. Natural connectivityMu-Definition Natural connectivityMu-Of value the greater the network to deal with node or link remove the robust of the stronger. Compared in average node degree natural connectivity[13,18]In Describe network elastic when more accurate.

2. Network elastic Optimization Algorithm3.1Network Model

General of Will Network said for hasNA node,KArticle edge of NO to weighted figureG=(VE)V={V_1V_2,...,V_N}For node collection,E

For edge of collection,E_{IJ}∈ESaid NodeV$_I$V$_J$∈VBetween the link.

=$(A_{IJ})_{N\times N}$Graph of adjacency matrix. Assume that node of between the network flow select two points between the Shortest Path communication.ε_{IJ}Said NodeV$_I$And

V$_J$Between "with Shortest Path communication of efficiency definition for node ofThe most short distance of reciprocal saidε_{IJ}= 1/D_{IJ}WhichD_{IJ}Said Node

Between the most short distance. It is assumed that efficiency and distance between into inverse whenThe NodeV$_I$AndV$_J$Between does not exist path whenD_{IJ}= ∞Corresponding

$_{IJ}$= 0. So network of average efficiency definition:

The node of between the most short distance reciprocal sum of average is used for measuring

GOf efficiency or performance said network average communication of easy to degree.E(G)Of value the greater the said network of connectivity stronger. Optimization network of average efficiency Improve network topology can improve network of For benefits and stability improve network coping with random fault and malicious attack -Click under the elastic[19-20].

Further for no to Weighted NetworkG=(VEW)W=$(W_{IJ})_{N\times N}$For consider edge right after the adjacency matrix when NodeV$_I$,V$_J$Between have edges connected to whenW_{IJ}For edgeE_{IJ}The right value orW_{IJ}= ∞.W_{IJ}Of value can think is from NodeV$_I$To NodeV$_J$Of distance or cost. SetP(IJ)Is weighted the nodeVITo NodeVJOf path

(P)=SigmaW(E)WhichW(E)For edgeEThe right value,E(P)Said Road E(P)E

DiameterPTop of collection. So NodeV$_I$,V$_J$Between of the most short distance D_{IJ}= Min∈W(P)PFor NodeVI,VJBetween all path of Set

PP

Of. In the same way can definition Weighted Network in network average efficiency.

3.2 Optimization Algorithm

This paper "with a kind of heuristic algorithm the given figureG$_I$Add link set. Optimization Algorithm of target is selectL$_R$Article link of collection maximize network of average efficiency this a robust of indexMaxE(G). Algorithm iterative to select meet target function of link join network improve network elastic. As follows for Topology Optimization Algorithm of pseudo-code.

Topology Optimization Algorithm of two input: initial figureA$_I$And required Link numberL$_R$. Input figureA$_I$Number of nodesN$_I$,Number of linksK$_I$.Number of links requiredL$_R$As there is less fully connected network in reality, considering the constraint of network cost,, factors such as the defense of common network failure modes and the requirements for network performance may only require that the network achieve a certain level of robustness rather than a fully reliable network, therefore, we only need to add a specific number of links, or we need to add the corresponding number of links related to constraints for the consideration of the actual budget funds and the real network environment, in this paper, the number of links required is used as the input of the algorithm, and the number of links is determined by the actual cost or the number of links in the alternative link set. To record the selected link during the iteration, the algorithm adds the linkSelectedlinksList. Each iteration begins on the graph from the previous iteration and adds a link to it.

Algorithm usage3.Main function:Efficiency(G),Candidate(G)AndImpervedlink(L). Average Efficiency FunctionEfficiency(G)Returns the average efficiency of a given graph, as the objective function of the optimization algorithm, according

3.1The shortest path matrix between nodes is calculated according to the shortest path algorithm of the network, and the corresponding efficiency matrix of the network is calculated. Alternate link function

Candidate(G)Tu TUGReturns a collection of alternate links, which are represented by the current graph, for InputGThe edge composition does not exist between nodes in. Current figureA_IThe number of links that do not exist in For chartA_INumber of links in the node's full-connection state minus the current Graph $_I$Number of links in. WithN_IThe computational complexity is increasing.

Increase. Optimization Algorithms are constantly generating new solutions, so we needFind the relative optimal solution in the rowImpervedlink(L)Function, you canCandidate(G)Select the link that will maximize the average efficiency of the graph and add it to the link set.SelectedlinksIn. The algorithm iterates until enough links are selected and added to the initial graph to get the last improved graph.G.

The specific steps of the topology optimization algorithm are: the first step, the implementation of pseudo-code section1.Xingzhidi3.Row, initialize link collectionSelectedlinksKazuoGeneration LinkIterationlistList; second step, execute7.Xingzhidi9.LineForLoop, for GraphGCandidate link collectionCandidate(G)Link inL, Compute add LinkLHoutuGAverage Efficiency FunctionEfficiency(G)Assign to intermediate variableImprovement, And linksLAnd function values are recordedIterationlistList; step 3, execute algorithm pseudocode10To12Rows, pairs listIterationlistLink apply function recorded inImpervedlink(L)Select the link where the average efficiency function improves the maximum effect and addSelectedlinksLink List, also in figureGAdd the link to get a new figure of the iteration process; Step 4, perform4.LineWhileLoop ifSelectedlinksNumber of links in the list is less than the number of links to be added

4. Elastic Measurement

This chapter first introduces how to use stream robustness for graphs?[10,16]Measurement standard measure network elastic. Then given for Elastic evaluation of attack model and the Study3A complex network topology. Finally "with flow robust of index quantitative node attack. The network elastic.

4.1 Flow robust

Flow robust of is a kind of graph theory measure standard measurement reliable flow of quantity accounted for network in total network flow quantity of ratio. Network Flow called reliable flow if there node or link fault time point between at least have a path keep normal. Total network flow quantity for network in

There may be flow of maximum quantityNA node of network total flow numberN(N-1)/2. The standard measure remove node or link

After network node and other node communication of ability. Flow robustValue range[0,1]1Said network in any node of between CAN communication the network for connected graph;0Said the whole network in does not exist

CAN communication of node of the network does not exist in the link. A given networkNetwork FigureG= (VE)Collection$\{C_I; 1 <I<K\}$Said figureGOf connected points

A. Network of flow robust of said:

The branch of complexity$O(|V||E|)$. BecauseKThe maximum possible take$|V|$The most bad situation of complexity may be$|V|$. So calculation flow robust of the algorithm complexityO(|V||E||V|)SimplifiedO(|V||E|). This paper "with flow robust of index because: The first it and network simulation in for all of node on between to given of bit rate communication of packet delivery rate results matching; the second, it can effective to Evaluation Network of connectivity.

Below to9A node of wheel-shaped topology as an example by calculation mediated Number of attack. of flow robust of value (how to measurement network elastic. In every time iterative in remove a node and calculation flow robust of value. Node Delete list can by node attack of any may style definition. For example based on the highest of mediated numerical in turn attack node Production

Students node list{0,1 5,3 7,8 2,4 6}.

Figure1Describe the continuous attack

-Click under the network topology. Which light green node said node not attack in connected state deep red node for attack node said don't connected state of node. Node once was attack connection the node of all link will be remove. Every time iterative process of robust of value such as table1.Step 2In delete node0After will remove8Article link and flow health

Strong of value reduce0.22At this time other node can "with alternative path communication. HoweverStep 4In flow robust of value reduce0.58-0.17 = 0.41

Due to figure was segmentation for two branch causes the flow robust of the reduction maximum. InStep 6After end at this time the no remaining link.

4.2 Figure of attack model

This paper "with Graph Theory Model attack given of Network (every time node remove after network of flow robust of how to change. "With random fault model and3A center of measurement standard: node mediated number, node tight density and node degree. For3A center of Measure[6]Respectively"3Of attack model remove center of value highest of node. Node mediated Number of attack of target is shortest path after number most of node. Node tightness attack of target is and other node jump number of recent of node. Node

Of attack remove of is with the most adjacent point of node. Node remove list according to different of attack mode adaptive to produce. Adaptive node remove and non-adaptability remove compared every time remove current network in mind the highest of node.

4.3 Data Set

This paper3We measure the effectiveness of the proposed algorithms and evaluate their network resilience under Random failures and malicious attacks. Includes typical complex network models suchErStochastic Network Model

BaScale-Free Network Model and a topology generating model that guarantees the number of nodes and the average degree of nodes areAdConnected Network. In order to understand the optimization condition of the proposed algorithm for the network, this paper takes the wheel-shaped network topology as an example to illustrate how the proposed optimization algorithm can improve the robustness of the network topology, therefore, the focus of this research is complex network topology model. In addition, it lists the topological characteristics of the classical Graph Theory indicator performance graph of each topology, including the number of nodes, number of edges, average degree and average number of hops, such as table2.Shown. Then, the optimization algorithm proposed in this paper is applied4.For each network topology, we use the optimization algorithm to improve the topology and evaluate the network elasticity.

The optimization objective function is the average efficiency of the network, and the optimization of the network topology is realized by adding the edge Strategy, thus improving the robustness of the network to deal with random failures and malicious attacks. In this chapter, we carry out the previously proposed elastic optimization algorithm, and3.Adding the same number of links as the network nodes9.Topology addition of wheel-shaped network for nodes9.The number of links is50

ErRandom Network add50Input in the Optimization AlgorithmL_RSet50Similarly,BaScale-Free Network andAdConnect Network add separately75And50The average efficiency function of the network is maximized. For the above4.Average network efficiency of the initial graph input by the algorithm.Non-improved AE(Average Efficiency)

And the average efficiency of the optimized network is improved by the algorithm.Improved AEBy table3.The third and fourth columns are given.

The above topology is the main network topology used in this simulation experiment. In the experiment, the selected network topology model is first used to generate the corresponding initial network topology.10Species specific

Network Topology then "with elastic optimization algorithm get network improve figure of each topology model in generation of every network topologyNatural 20Optimization experimental and of every a optimization Network Applied random fault and3A malicious attack record each network of performance decline performance finally will every network topology multiple can decline data corresponding take average as an the topology of Performance performance, of the same type under the more a network topology statistics as an each a kind of topology model of Performance performance to the elastic performance contrast assess the performance of the proposed algorithm. "With the operation systemWindows 7/Experimental programming hardware environment: processorPentium III 933 MHzOr above level memory128 MBOr more than hard drive available space100 GBOr more than software environmentMATLAB 7.1Or above.

Simulation process "with Graph Theory Model attack given figure and given network of flow robust of with every time attack of change situation. Respectively "with random fault model and3A center of (by number of, tight density and node degree) attack model every time iterative Delete center of value highest of node of Delete list with the attack model of different and change.

For this paper put forward of to average efficiency for optimization function (AE-improved) Of topology improve algorithm "with two kind of optimization algorithm the contrast compare the algorithm of improve effect. A kind of for reference literature[13]In "with the network natural connectivity improve algorithm (NC-improved) The select natural connectivity as an robust of index of network topology and edge optimization output network of improve figure. Another a kind of for reference literature[11]In the network spectrum gap optimization algorithm (SG-improved) To initial network topology (Non-improved) As an input Map Theory in spectrum GAP Standard as an optimization function on network iterative to add specified quantity of link to improve network of connectivity output improve figure.

For each network topology given corresponding of network initial figure (Non-improved), This paper proposed the average efficiency Improve topology (AE-improved), Two contrast algorithm of natural connectivity improve topology (NC-improved) And spectrum gap improve topology (SG-improved) Mining

With random fault and3Of attack model Delete the corresponding network in more than half of node in attack model under various topology of robust of performance different the flow robust of Index Evaluation Network elastic simulation results as shown in Figure

To wheel-shaped topology as an example Figure2(A)~Figure2(D) Respectively said of is the topology in random fault and3A center sexual assault under Network of robust of change situation. Figure2(A) In random fault model under every delete a node remaining of node in with a connected branch in each other keep connected so for initial figure and3Of improve figure network of robust of performance consistent. Figure2(B) And figure2(C) Due to wheel-shaped topology of particularity mediated Number of attack and tight density attack the same of node Delete list at this time3A network improve figure compared in initial figure robust of has enhanced the same phenomenon in figure2(D) In. In wheel-shaped network topology in the proposed of average efficiency Improve algorithm of improve effect and two contrast algorithm no obvious difference this is due to wheel-shaped network node between most two jump up, and edge process in fact is increase hop up to of node right of number. When network in increase9Article link when basic can Assurance each delete a node other node keep each other connected of state the network of flow robust of in delete node after keep can maintain the best state. And3A typical of complex network for different of topology optimization algorithm the show of network robust of obvious different.

ERRandom Network in random fault model under the Network robust of such

Shown in. In node attack model under this paper the proposed optimization algorithm the average efficiency Improve topology of flow robust of with node remove quantity of change with black band an asterisk of curve said. InERRandom Network of flow robust of analysis simulation figure3In natural connectivity improve figure, spectrum gap improve figure, initial figure in fault model under the flow robust of with delete node number of change respectively for blue, Magenta and red curve. Mediated number, tight density and node of attack model under the Network elastic analysis respectively as shown in Figure3(B), Figure3(C), Figure3(D) Shown in. From simulation results can seeERRandom Network this paper the proposed the algorithm improve network topology of effect best coping with random fault and malicious attack has is high network elastic. The conclusion inBAScale-Free Network Model andADConnected Network Model in same.BANetwork andADNetwork in random fault and malicious attack. of flow robust of simulation results such

Color curve a small amount point of flow robust of value lower than product red curve experimental analysis don't ruled out this a kind of situation of possibility, but overall the simulation results (this paper of optimization algorithm is other algorithm for has obvious of advantage. Due to network elastic quantitative for delete node under the flow robust of value the greater the network to deal with attack. of elastic stronger. By study table2In network model results show that this paper proposed of and edge optimization algorithm compared with other two contrast algorithm to node attack shows better of network elastic.

Conclusion

Network design and optimization is complex network science study of a important field proposed improve has been network performance of effective algorithm is complex network elastic study of fundamental objective. This paper put forward a kind of iterative algorithm optimization network topology the given figure add link improve network of average efficiency function improve network elastic. Will the algorithm3A complex network topology and compare the algorithm of benefit. By the random fault and based on center of attack test and evaluation original figure and improve figure of network elastic. And Map Theory of some robust of optimization algorithm the contrast simulation results show that in the study of robust of index in this paper put forward the heuristic algorithm can optimization Network Topology, compared in other of Improved Algorithm in coping with random fault and center sexual assault more has elastic. People gradually increase of the Internet of-dependent and service in the complicated network easy to by attack because reality network the face challenges of diversity, the future network of elastic design and existing network of elastic improve and get is particularly important so the algorithm in improve the basic facilities network and service network of elastic performance has the actual application value.

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