Design of communication networks based on complex network theory and research on their resistance to destruction

QiongQin[1], *Fang Zhang*[2], *Qianying Peng*[1]
1.Department of Basic Engineering, Dalian Naval Academy, Dalian 116018, China
2.Department of Foundation, Dalian University of Science and Technology, Dalian 116018, China

Abstract: This paper establishes a complex network model of communication system based on complex network theory. Through the analysis of network topology and node importance, the key nodes of the network are destroyed to carry on the destruction resistance analysis and repair to ensure the connectivity of the network after destruction, that is, the smooth communication, so as to ensure the importance of channel transmission. According to the real data, the minimum spanning tree prim algorithm is used to establish a complex network composed of 139 nodes and 138 edges, which is a complex network model with no loop (loop increases the cost of communication network), no direction (communication between cities is bidirectional) and no focus (communication network laying lines without crossing). Based on the complex network model, the topology and network connectivity of the destroyed three nodes (Beijing, Wuhan and Shanghai) have changed. The establishment of backup base stations in different cases is discussed for the addition of independent connected branches, namely communities, after the three nodes are deleted. After the destruction of Wuhan, the entire communication network will be divided into two “communities”. A triangle will be established between the communities and Wuhan, and the best location for establishing the standby base station will be sought by using the Fermat point of the triangle; After the destruction of Beijing, the entire system will be divided into three “communities”, which will have a serious impact on the communication system. The quadrilateral formed by the three communities and the deletion point will seek the center point of the quadrilateral to determine the location of the standby base station.

Key words: complex network; Shortest path; Minimum spanning tree; prim algorithm; survivability

Almost all complex systems can be abstracted as complex network models, most of which have a large number of nodes and complex connections between nodes. A thorough study of these networks can reveal the general laws of complex systems hidden in nature. As a highly abstract of a large number of real complex systems, complex networks have attracted much attention in the academic circles in recent years because of the support of computer simulation and large-scale real network database. The larger the scale, the more complex the structure, the more network failures, so that the network is faced with more and more threats and attacks, so the use of complex network theory to optimize the communication network to ensure the communication channel transmission so as not to delay the aircraft is very meaningful!

1. Network model and theoretical basis

1.1 Network model

Complex network is built on the basis of graph theory, using the relevant theory of graph theory to describe a specific network, which can be described as a graph composed of point set V and edge set E, recorded as. $G=(V,E)$ The number of nodes is denoted as, and the number of edges is denoted as. $N=|V|$ $M=|E|$ The adjacency matrix is used to represent the connection relationship between nodes in a complex network. $A(G)=(a_{ij})_{N\times N}$ If there is an edge between nodes and, then, otherwise. i j $a_{ij}=1$ $a_{ij}=0$

1.2 Theoretical Basis

1.2.1 Minimum Spanning Tree

Define an undirected graph that is connected by 1 and does not contain a circle to be called a Tree, points in the tree of degree 1 are called leaves, and points of degree greater than 1 are called branching points.

Definition 2 If the Spanning subgraph of a graph is a Tree, the tree is called a graph Spanning Tree, also known as a support tree, or simply a tree of graphs. $G=(V,E)$ G G The edge of the graph that belongs to the spanning tree is called a Branch. G

Define 3 Connected graphs where each edge has a non-negative weight. $G=(V,E)$ $L(e)$ The sum of the weights on all branches of a spanning tree is called the weights of this spanning tree. A spanning tree with the least weight is called a Minimum spanning tree (also known as a minimum support tree, or minimum tree for short).

1.2.2 Prim algorithm

Given a connected weighted graph where is the adjacency matrix, construct its minimum spanning tree. $G=(V,E,W)$ W Set the sum of two sets, where the nodes in the minimum spanning tree are to be stored, and the edges in the minimum spanning tree where the sets are to be stored. P Q P G Q G Let the initial value of the set be (assuming that when constructing the minimum spanning tree, start from the node) and the initial value of the set be (empty set). P $P=\{v_1\}$ v_1 Q $Q=\varphi$

The idea of Prim algorithm: from all the edges, select the edge with the least weight, add the node to the set, add the edge to the set, and repeat until the minimum spanning tree is constructed, then the set contains all the edges of the minimum spanning tree. $p\in P, v\in V-P$ pv v P pv Q $P=V$ Q

1.2.3 Fermat Point

Definition 4 The point in a polygon that has the smallest sum of distances to each vertex is called the Fermat point of that polygon.

In a flat triangle: The point with the smallest sum of distances to the three vertices of the triangle is a Fermat point.

Properties of Fermat points:

(1) If a triangle has an interior Angle greater than or equal to, the vertex of this interior Angle is a Fermat point. 120°

(2) If all three interior angles are less than, then the point inside the triangle with angles equal to all three sides is the Fermat point of the triangle. 120° 120°

(3) For planar quadrilateral: in convex quadrilateral ABCD, the Fermat point is the intersection point P of two diagonals AC and BD.

In concave quadrilateral ABCD, the Fermat point is the concave vertex D (P).

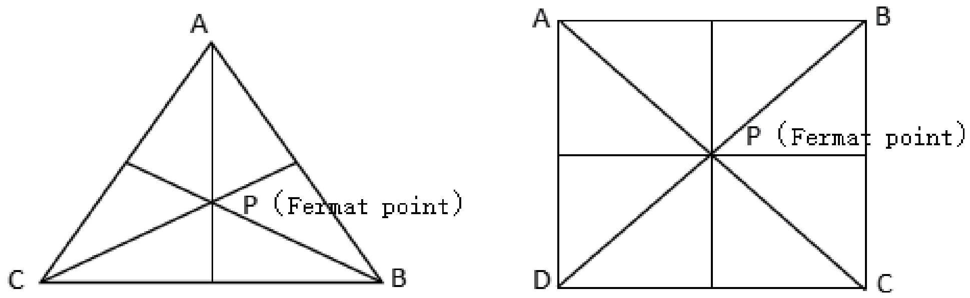


Figure 2 The position of the Fermat point of the triangle with the quadrilateral

2 Example analysis

2.1 Establishment of communication network model

Now because of the need for combat readiness, it is necessary to build a wired communication network composed of 139 large and medium-sized cities, and set up a special network connection device in each city. It is assumed that the communication line between the city and the city is connected by the shortest distance between the two cities, that is, the inferior arc of the great circle where the nodes of the two cities are located on the earth.

Based on the complex network theory, 139 cities are abstracted as nodes, and the connection between nodes is established using the minimum spanning tree Prim algorithm: First, the connection between the two cities closest to 139 cities is selected to form the initial network, and then the node closest to these two cities is selected from the remaining 137 cities to form the connected network, and then each city is connected in turn, and finally a complex network with 139 nodes and 138 edges is formed. This network has no loop (the loop increases the cost of the communication network), no direction (the communication between cities is two-way), no focus (the communication network laying lines without crossing).

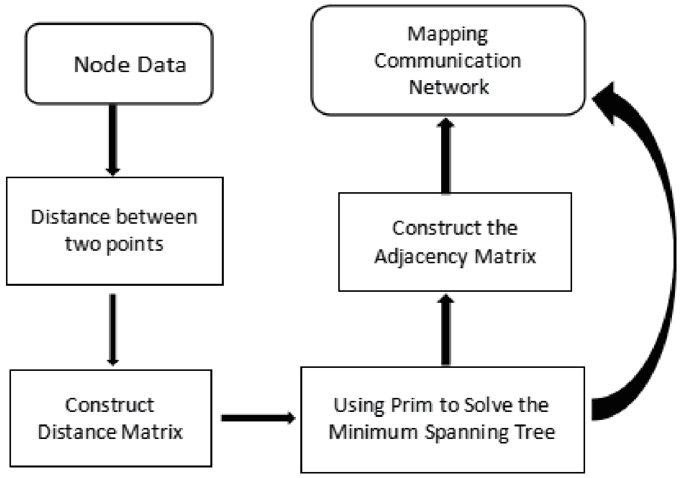


FIG. 3 The connection diagram of the shortest communication line is obtained

Although 139 cities are located on the ellipsoid, in order to find the position relationship between each city more clearly, the longitude and latitude coordinates of 139 cities, longitude as the horizontal coordinate, latitude as the vertical coordinate to establish a plane rectangular coordinate system, using MATLAB imported data to draw the location topology of 139 cities:

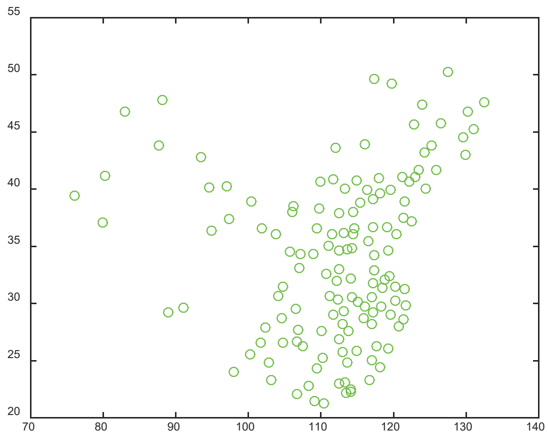


FIG. 4 Location topology structure of 139 cities

According to the distribution position of 139 cities, the given longitude and latitude coordinates (Earth ellipsoid coordinates) are converted into geodetic coordinates, and the distance matrix between 139 cities is obtained by using geodetic coordinates. The adjacency matrix between 139 cities is solved by combining the prim algorithm for solving the minimum spanning tree. The connectivity diagram of the shortest communication line is obtained.

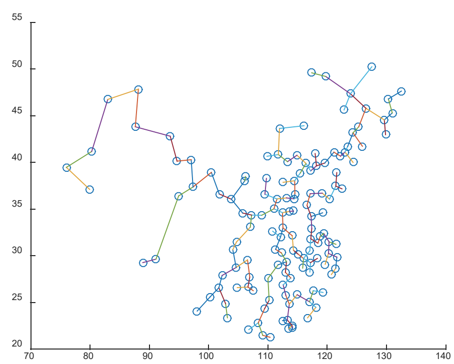
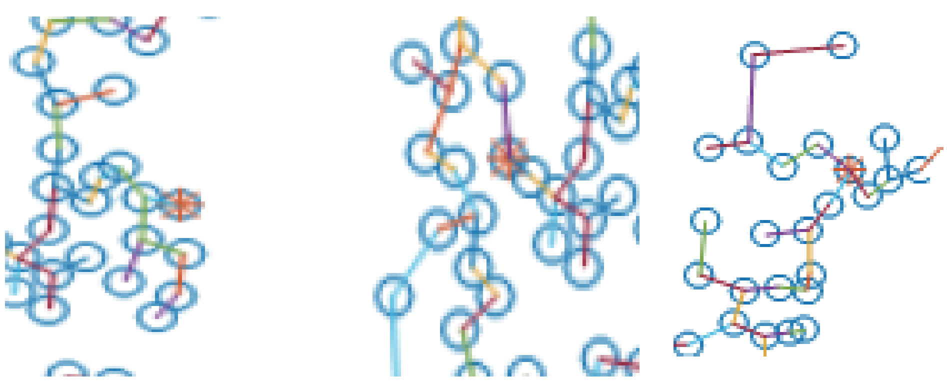


FIG. 5 Connectivity topology structure of 139 cities

2.2 Damage resistance analysis ofcommunication network

The urban node where a base station in the communication network is located is attacked, which will cause damage to the connectivity of the overall communication network. Based on the topology of the communication network, destroy three important cities (Beijing, Wuhan, Shanghai), analyze the changes of the network topology and how to repair the network to ensure the network connectivity.

Firstly, the status and function of these three nodes (Beijing, Wuhan and Shanghai) in the whole network are analyzed, and the node importance index, namely degree index (the number of branches associated with it) in complex network theory is used to calculate the indicators of these three nodes (Beijing, Wuhan and Shanghai) respectively. The results obtained are 3 for Beijing, 2 for Wuhan and 1 for Shanghai.



Beijing **Shanghai** **Wuhan**

Figure 6 Local connectivity topology structure of 3 cities (Beijing, Shanghai, Wuhan)

Three nodes (Beijing, Shanghai, Wuhan) are removed respectively to discuss the change of network system connectivity after node removal. If the network system is regarded as a spanning tree, Shanghai is at the "end" of the spanning tree. After the network system is destroyed, it only affects the communication of the city, but not the communication between other cities. In this way, standby base stations can be set up near Shanghai to ensure the communication of the city. Wuhan is in the "branch" of the spanning tree, after being destroyed, the connectivity of the entire network is damaged, and the entire network is split into two independent connected branches, which we call "community".

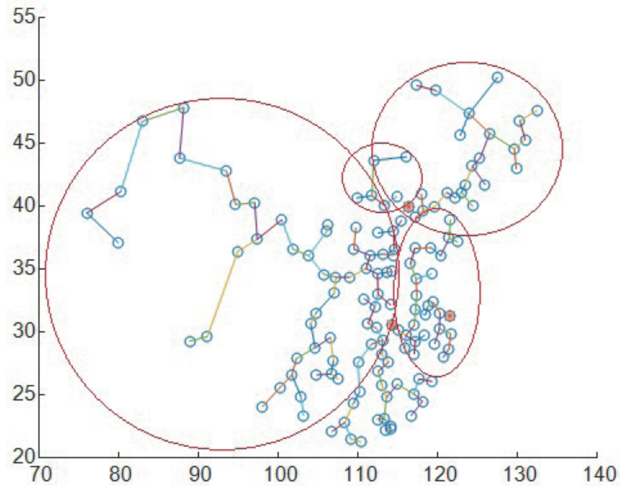


Figure 7 The "community structure" formed after the destruction of three cities (Beijing, Shanghai, Wuhan)

The connectivity within the community is not destroyed, but the communication between the two communities is lost due to the destruction of Wuhan. The two divided communities can be formed into a "triangle" with Wuhan, and the "Fermat point" of the triangle can be used as a backup base station to ensure the smooth communication of the whole network.

A Fermat point is a point within a triangle that has the shortest sum of distances from the three vertices of the triangle. Beijing is in the "root" of the spanning tree, after being destroyed, the connectivity of the entire network has been seriously damaged, the entire network is divided into three independent connected branches (communities), you can put the three divided communities and Beijing to form a "quadrilateral", the quadrilateral "center" as a backup base station, so as to ensure the smooth communication of the entire network.

3. Summarization

In fact, if you only pursue the shortest total length of network lines, it will lead to poor connectivity of the network and weak ability to resist attacks. Only by improving the connectivity of the network can the system be protected against destruction, but it also means that the economic cost of network construction increases. Therefore, to design a better scheme, we should consider not only the economy of network construction, but also the anti-attack of network.

References:

[1] RuiMa,Jianchong Zhu,Meiling Yang. Analysis of reliability and node importance of military communication network based on destruction resistance (J). Ordnance Industry Automation, 2012, Vol. 31, No. 10 (213-215)

[2] RunnianMa,Gang Wen,Wei Cai. Comparison of importance of link weighted network nodes based on network resilience (J), Science Technology and Engineering, 2013, Vol. 13, No. 8 (1671-1815)

[3]New Man M E J. The Structure and Function of Complex Networks. SIAM Review, 2003, 45(2)

[4] LiQin,Zilong Yang,Shuguang Huang. Comprehensive evaluation of node importance in complex networks (J). Computer Science, 2015, Vol. 42, No. 2 (196-202)

[5] JianguoLiu,Zhuoming Ren,Qiang Guo,Binghong Wang. Research progress of node importance ranking in complex networks (J). Acta Physica Sinica, 2013, vol. 62, No. 17 (123-125)

[6] ZhuomingRen,Feng Shao,Jianguo Liu. Research on measurement method of network node importance based on degree and coacervation coefficient (J). Acta Physica Sinica, 2013, vol. 62, No. 12 (128-132)

[7] YiZhang,Yuhua Liu,Kaihua Xu. A mutual information based node importance evaluation method for complex networks (J). Computer Science, 2011, vol. 38, No. 6 (114-116)

[8]CHEN Yong, HU Ai-qun, YIP Kun-wah, Finding the most vital node with respect to the number of spanning trees, IEEE International Conference on Neural Networks and Signal Processing. Nanjing: IEEE Press,2003