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Brief Analysis on the Construction of Network Capacity Reliability Model

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Abstract: At present, network capacity reliability is a hot topic in network reliability theory. Capacity reliability is generally defined as the probability that a network can transport a specified number of network flows (demand traffic) from a source point S to a sink point T under certain conditions. Capacity reliability takes into account not only the connectivity of the network, but also the characteristics of flows in the network, the capacity limits of edges and the capacity level of the network. Therefore, most researchers believe that capacity reliability is a more comprehensive and reasonable description and interpretation of the performance of polymorphic network systems. Based ON the analysis of the existing definition of network reliability, this paper evaluates the defects of existing network reliability, and gives the definition of network capacity reliability for directed polymorphic networks.

1. Analyze Existing Network Reliability Definitions

1.1. Existing Network Reliability Definition

At present, most of the network reliability analysis starts from the basic definition of reliability, analyzes the situation of network reliability, and puts forward the purpose of network reliability research to summarize: to find ways to deal with different destructive interference and influence, so as to improve the reliability of the entire network operation. The network can better serve the task requirements in a variety of conditions. Based on this, some people put forward a new definition of network reliability in the broad sense of network reliability: Network reliability refers to the ability of the network to meet most users' service functions under the circumstances of various interference factors during its normal operation cycle.

According to the existing research status, there are the following five definitions of network reliability:

Definition 1: The viability of a network under prescribed conditions and for a specified period of time under man-made or natural destruction [1].

Definition 2: The ability of a network to fully fulfill a specified communication function under a specific environment and within a specified time under the action of man-made or natural destruction

[2]. Environment, time, and fully completed functionality are the three elements of this definition.

Definition 3: The degree of maintaining normal services when transmission or switching faults occur or traffic exceptions occur [3].

Definition 4: The probability that the desired information can be successfully transmitted from the source to the destination [4].

Definition 5: At a given time interval, the probability that a network part will perform a required function under a given condition [5].

1.2. Defects in the Existing Network Definition

The first definition and the second definition are evolved from the most common definition of reliability, emphasizing the influence of nature or people, the first definition focuses on the survivability of the network, the second definition focuses on the effectiveness of the network. The third definition is the most common definition of network reliability, that is, the stable quality of the network. For this reason alone, it is probably more appropriate to use the definition "availability"; the fourth definition is the reliability definition based on the comprehensive consideration of the organization and structure of the network. In addition, many articles have discussed network reliability. However, none of the articles gave the exact network reliability. For example, it is written in the literature that there are various definitions of communication network reliability [6], and the network reliability is summarized from the aspects of the whole network, important end, disaster and so on, CCITT proposes to define the network in terms of reliability, maintainability and supportability [4]. At the same time, we try to clarify the relationship between them, but these so-called definitions are only the reliability definition of each component of the network, they can not be applied to the whole network, nor do they involve the concept of network capacity and polymorphism.

1.3. Definition of Capacity Reliability for Polymorphic Networks

In this paper, the definition of capacity reliability of polymorphic networks is given as follows:

Capacity reliability of a polymorphic network: It refers to the capacity state of the edge of a directed network in the whole process of its operation meets the polymorphism, and the traffic to be transmitted from the source point to the sink point is d. Under the condition of coexistence of various destructive factors or disturbances, the maximum flow in the network is greater than or equal to d.

The measure to evaluate this capability can be called network capacity reliability, which can be expressed by the following formula.

$$R_d = Pr[Flow_{Max} \geqslant d] \tag{1}$$

This definition reflects the ability of the network to transmit traffic as the first evaluation index. The measure in this definition is the ability of the network to meet the transmission requirements. This can not only consider the connectivity under normal working conditions, but also study the reliability of the traffic network when problems occur, which is a comprehensive consideration of the network operation process. In this way, this measure is an improvement over the content covered by the previous definition, and can fully show the research characteristics of network capacity reliability, that is, it takes into account the concept of capacity and the polymorphism characteristics of the edges in the network. Because edges in a network are not just working and not working. The definition does not mention the concept of time, but this does not mean that time is not considered in the evaluation of network reliability. The calculation of network measurement index can also be said to be a comprehensive consideration of network working index and capability within a specific period of time under certain requirements. The measure adopted in the simulation part of this paper is the ability of the polymorphic network to meet the specified traffic transmission within the specified task time.

2. Construction of the Network Capacity Reliability Model

The network considered in this paper is a polymorphic directed network and the point to point transmission is studied. Therefore, the source and sink points of the network must be determined first. After determining the source point and sink point of the network, denote the source point by S and the sink point by T. Label all intermediate nodes in the network in sequence, ranging from 1 to n. The edges in the network are also labeled sequentially, from 1 tom. In this paper, we consider the capacity reliability of the network, so each edge should be assigned two properties related to capacity. The first property is the maximum capacity state, which represents the maximum amount of traffic that can be transmitted by this edge, denoted by wi. The second attribute is the current capacity of the state, because in the network edge to meet the polymorphic, so the current edge all carried out in accordance with the maximum capacity state transfer, not by Xi, Xi values for the positive integers on the interval [0, W]. W is the maximum capacity state, which indicates the working state when the network is completely normal. 0 means that there is a failure on this side and the amount of traffic that can be transmitted is 0. Unlike an edge, a point has two states, only working and failing. At the same time, how to convert point failure into link failure will be given in the simulation section. A point in the network does not need to consider the attribute of maximum capacity state, and the incoming and outgoing traffic of a point is infinite. Besides the source point and the sink point, the incoming traffic of other nodes is equal to the output traffic. The proposed polymorphic network capacity reliability model is shown in Equation 1.

$$G=\begin{cases} V=\{S,n_1,n_2,\dots,\ T\} \\ E=\{e_1,e_2,\dots,e_m\} \\ W=\{w_1,w_2,\dots,w_m\} \\ X=\{x_1,x_2,\dots,x_m\} \\ N_{in}=N_{out}\ \ (N\neq S,T) \\ Flow_{\max}=\sum C_i \end{cases} \tag{2}$$

G (V, E, W, X, Flowmax) is used to represent random flow network, $V=\{S,n_1,n_2,\dots,\ T\}$ represents the set of points in the network, S represents the source point. T represents the sink point, n1, n2, …, nn represents nodes in the network except the source point T and the sink point S; Set $E=\{e_1,e_2,\dots,e_m\}$ represents the set of edges in the network, mrepresents the total number of edges; $W=\{w_1,w_2,\dots,w_m\}$ is a state vector composed of the maximum capacity states of each edge in the network, where Wi (1≤i≤m) is the maximum capacity state of edge ei, let xi denotes a particular value of the capacity state of edge ei, and xi can only be a positive integer value between the minimum capacity state, which is 0, and the maximum capacity state. $X=\{x_1,x_2,\dots,x_m\}$ is a state vector composed of the capacity states of each edge in the network. It indicates the current capacity state of each edge in the network. Let Flowmax (X) represents the maximum flow of the network under the state vector X. Nin denotes the indegree of a point, Nout is the degree out of a point. $\sum C_i$ represents the sum of the current capacity values of all edges connected to the sink T.

When nodes and edges fail, two situations are considered at this time, one is an unrepairable network, and the other is a repairable network. In the unrepairable network, once the points and edges fail, they are directly set as failure in the sampling of the epicycle simulation. In repairable network, after point and edge failure, maintenance will be carried out with a certain probability. Maintenance may succeed or fail. If maintenance fails, this round of simulation will be set as failure. If the maintenance is successful, after a certain maintenance time, the failed point or edge will be restored to normal work, and the failure time sampling will be carried out again. The following is an example of how to construct the network model proposed in this paper.

In a random flow network as shown in Figure 1, V={s,1,t}, n=1, E={el,e2,e3}, m=3, W=(3,2,1); given a state vector X=(1,2,1). Then, the maximum network traffic under X is Flowmax (X) =2.

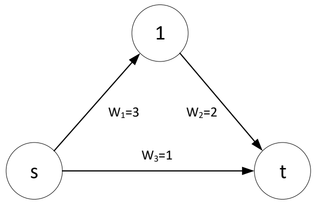

Figure 1: Simple random flow network

The conditional assumptions of the network capacity reliability model constructed in this paper are as follows:

(1) If the reliability of a node is not permanently set to 1, a node failure is converted into a link failure.

(2) Each edge in the network satisfies polymorphism, and the capacity state of each edge is a random variable (taking the positive integer value between 0 and the maximum capacity state), and it should obey the assumed probability distribution.

(3) The capacity state of each edge in the network is completely independent.

(4) The faults of each edge in the network are completely independent, and the faults of each edge will not cause the faults of other links.

(5) The node capacity is infinite, and the flow in the network satisfies the flow conservation law, that is, the flow into a certain point (excluding the source point S and the sink point T) is equal to the flow out of the node.

(6) The network topology remains unchanged

(7) Source point S and sink point T will not fail.

3. Conclusion

This paper first analyzes the existing definitions of network reliability and their defects, and then gives the definition of polymorphic network capacity reliability which is suitable for this paper. Based on the definition, THIS paper discusses THE construction of THE capacity reliability model of polymorphic networks. Based on the consideration of network connectivity and capacity, the network elements, points and edges, are taken as the basic components, and the maximum capacity state attribute is assigned to each edge. There is another set of state vectors to represent the current pass capacity state of each edge. At the same time, the network needs to meet certain assumptions.

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