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Analysis on Network Performance of two kinds of Information System

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Abstract. "Tree" structure is a typical structure of information system in great-industry era, characterized by a hierarchical communication of command from top to bottom, and a hierarchical report of information from bottom to top. A network model of "tree" information system is established and the performance is studied by complex network theory. The advantages and disadvantages of these two types of networks in performance are summarized by contrastive analysis of the "tree" network and fully connected network, and a technical design plan of information system to meet the requirements of the information age is proposed finally.

Keywords: "tree" information system; complex network theory; fully connected network

1 Introduction

Traditional information systems grow out of the large industrial era, so information exchange relationship between the components shows a hierarchical communication of command from top to bottom, and a hierarchical report of information from bottom to top. If the system components are abstracted into network nodes, and the interactions of existing information between the components are abstracted into network links, the established network model of information system has a "tree" structure. The current society is in transition of historical stage from large industrial era to the information age, so how to design and achieve an ideal information system to meet the requirements of the information age is worth thinking and researching. According to the existing research results [1-5], it is feasible to establish the network model of the existing system and apply complex network theory for investigation.

2 Modelling study on mathematical models of "tree" network and fully connected network

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2.1. Premises and assumptions of modeling

(1) Network node types are divided into command-issue node and command-response node.
(2) The command-issue nodes of each level can exchange information between upper and lower levels.
(3) The command-response nodes of each level can only exchange information with corresponding command-issue nodes.

2.2. Establishing "tree" network model

Assuming the network model of a "tree" information system includes a total of 300 nodes—50 command-issue nodes and 250 command-response nodes. The network model of a "tree" information system is shown in Fig. 1.

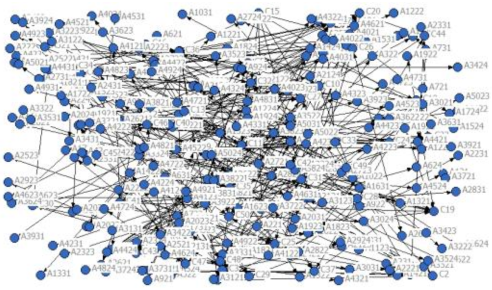

Fig.1. 2D view of "tree" network model

2.3. Mathematical model of fully connected network

Fully connected network model is an idealized information system network model, in which each node in the network is directly connected with each other. The model is shown in Figure2.

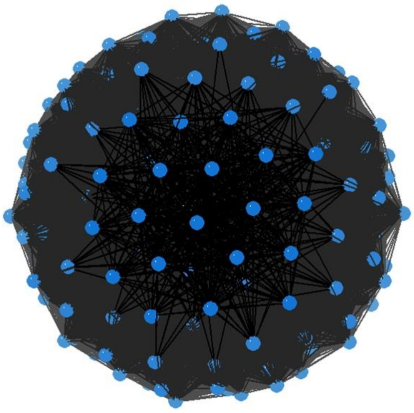

Fig. 2. 3D view of fully connected network

3 Contrastive analysis of the "tree" network and fully connected network

3.1. Classification and measurement of network performance

(1) Network density [1] is:

$$D = \frac{2m}{n(\mathrm{n}-1)} \tag{2}$$

where m is the number of actual links of network and n is the number of network nodes.

(2) Transfer efficiency of information. The average length of paths L is the mean value of the distance between any two nodes in the network [2], namely

$$L = \frac{1}{\frac{1}{2}N(N+1)} \sum_{i \geq j} d_{ij} \tag{3}$$

where N is the number of network nodes, d_{ij} is the distance between any two nodes in the network, namely the number of sides in the shortest path of two nodes.

(3) Network efficiency. The calculation formula is as follows.

$$GE = 1 - \frac{V}{\max(V)} \tag{4}$$

V is the number of redundant links.

(4) The cluster coefficient of node V_i can be expressed as:

$$C_i = \frac{2E_i}{\left(k_i\left(k_i - 1\right)\right)} \tag{5}$$

The cluster coefficient of the complex network $G(V, E)$ can be expressed as:

$$C = \frac{\sum_{i=1}^{|V|} C_i}{|V|} \tag{6}$$

3.2. Contrastive analysis of network performance

The performance indicators of "tree" network and fully connected network that are both with 300 nodes are shown in the table below. Contrastive analysis of network performance is conducted combined with indicators.

Table 1. Performance comparison of "tree" network and fully connected network.

Indicator	"Tree" network	Fullyconnected network
Network scale	300	300
Link	598	89700
Link-node ratio	1.993	299
Network density	0.0067	1
Cluster coefficient	0	1
Average length of paths	7.139	1
Network efficiency	1	0

3.2.1 Network construction cost: The above table shows that the network density of "tree" network is 0.0067, while the network density of a fully connected network is 1. Therefore, the relative cost of "tree" network is very low, but the extent of the information network is very low, so the relative cost of building a fully connected network is higher as it is also with the highest degree of informatization. Link-node ratio is a measure of the average cost of building the network, namely the average cost of each node added into the network. The above table shows that the link-node ratio of "tree" network is 1.993, indicating that on average about two links per node interact with the other nodes. The link-node ratio of fully connected network is 299, indicating the average cost in building fully connected network is higher than that of "tree" network in the same conditions.

3.2.2 Transfer efficiency of information: The above table shows that the average path length of "tree" network is 7.139. While the average path length for a fully connected network is 1. It can be seen the transfer efficiency of the "tree" network is low. The average path length for a fully connected network is 1, indicating the information transfer efficiency of fully connected network is maximal, which also means the information can be passed to other nodes via a link by any node in the network.

3.2.3 Network efficiency: The above table shows that the network efficiency coefficient of “tree” network is 1, which indicates no redundant links in “tree” network, and the network efficiency reaches maximum. But since no redundant links exist, there is no redundant link as a backup to maintain the normal operation of the network when subject to network attacks or partial failure, which means the robustness of the “tree” network is poor. Efficiency coefficient of fully connected network is 0, mainly because any node of the fully connected network has direct interaction with other nodes, with the largest redundancy, thus the lowest network efficiency, however, the robustness of is the best.

3.2.4 Information monitoring ability: The above table shows that the information monitoring ability of “tree” network is 0, as each node in the “tree” network cannot obtain the information of other nodes through direct information exchange. Clustering coefficient value of a fully connected network is 1, which shows that the node that has the ability to monitor the information existing in fully connected network.

4 Conclusions

The main advantages of “tree” network include low cost, high network efficiency while the main disadvantages are low efficiency of information transfer, poor network robustness, and poor information monitoring ability; the main advantages of fully connected network are high efficiency of information transfer, strong information monitoring ability and high network robustness while the main disadvantages are low network efficiency and high cost. Neither “tree” information system nor the “fully connected network” information system is the ideal one that can meet the need of information age information systems due to the shortcomings. But as both of the two systems have some advantages of the ideal information system, they can be studied, providing reference for designing ideal system to meet the requirements of the information era.

Finally, two kinds of information technology solutions for the design and implementation of ideal information system to meet the requirements of the age are proposed. First, it is optimized on the basis of the “tree” information system and the system is attached with the advantages of “fully connected network” information system through certain payment with the retention of original advantages. The second one is to optimize the “fully connected network” information system, minimizing the cost in the condition of the advantages of “tree” information system retained.

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