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## Design of a New Type of High Reliability Elementary Network

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### ABSTRACT

*This paper introduces the design of a new type elementary network. This network can be applied in the field that needs flow-control, jam-control to get the optimal route such as traffic conductor, industrial control, security monitor. It consists of physical layer, data link layer and network layer, its topologic structure reconstructs traditional network, forming a new pattern “田” shape network. The network includes network monitor and control station NMS, measuring and control units MCU. NMS is a PC computer which providing distributed operator interface. Operator can collocate every MCU through the interface, manually control every MCU to execute proper operation, receive and process data transmitted from MCU. MCU is high-grade self-governing. It can measure, store data all by itself according to the system configuration without the manually interposition. Under the condition when certain point of network link or node have trouble, MCU can transmit the data through the other routes, it also can automatically choose the best way on the basis of the communication quantum of the network.*

### 1.INTRODUCTION

The traditional elementary network which is applied in the field such as industrial control, security monitor generally include physical layer, link layer and network layer, it's topologic structure adopt BUS structure or TREE structure.

BUS network adopt BUS as its transmission medium, all nodes share BUS which is passive. Bus network is facility to install and cost litter than other mode. In order to avoid long-wire signal reflex which could causes transport error, we should matching terminal impedance, but under the condition when certain point of BUS network physical layer or link is broken then the whole network sink paralysis.

TREE network's topologic structure actually develop and extend from STAR

network, its structure layer, include base node and each branch node. When certain point of base node is broken, then the whole network can not work normally.

In order to improve the reliability of network and overcome the defect of the network which we discuss above, we reconstruct a new pattern“ 田 ”shape network. Under the condition when certain node or link of the“ 田 ”network is broken, signal can automatically transmission to aim through other link. Each node which constitute “田” network have intelligence, it can adjust route according the communication quantum of the network and make the whole network optimize. Situation which require high reliability and have dense sensors such as traffic conductor and fire alarm could adopt “田” network. We will discuss the structure of the “田” network in following.

## 2.THE CONNECTION OF THE “田” NETWORK

the connection of the whole network is shown in Fig.1. In connection Fig.1

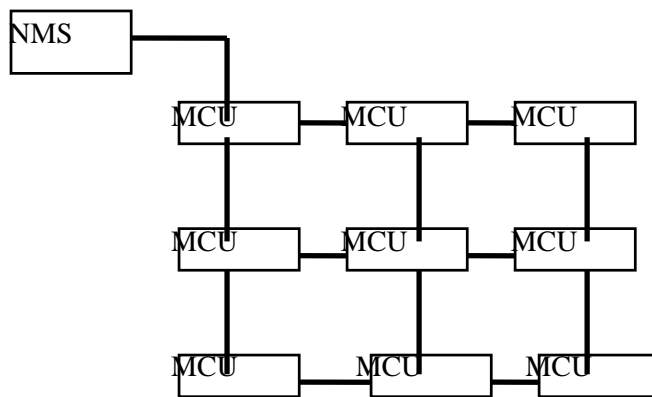


Fig.1 Connection of the whole network

NMS is network monitor station, it is a PC computer which providing distributed operator interface. Operator can collocate every MCU through the interface, manually control every MCU to execute proper operation, receive and process data transmitted from MCU. MCU which is made of A/D converting and manipulating board, communication board and main board, using node-driving pattern, is high-grade self-governing. It can measure, store data all by itself according to the system configuration without the manually interposition. Under the condition when certain point of network link or node have trouble, MCU can transmit the data through the other routes. MCU also can automatically choose the best way to transport signal to the aim according to the communication quantum of the network and the delay time that signal transport.

### 3.INTELLIGENCE ANALYSE AND REALIZE OF MCU IN “田” NETWORK

The function of a routing algorithm in a network is to deliver packets form a source node to a destination node. The transmission of data from source to destination in partially connected networks requires routing decisions at the intermediate nodes to guide the message along the best possible route. The choice of a route is generally based on some criterion. MCU in “田” network use delay time of signal transmission and communication quantum of the network as its optimization aim, and then it can chose it’s optimal route. We adopt dynamic distributed route algorithm. In order to obtain optimal route we must calculate the communication quantum of each link and the delay time of signal transmission.

#### 3.1 “田” NETWORK DESCRIPTION

The “田” network is a member of a class of multiply-connected, regular, mesh-configured networks. Logically, the links form a grid on the surface of torus. There is an arbitrary number of rows and columns with four links arriving and leaving each node.

Though it is possible, “田” network does not lose packets because of buffer overflows. The motivation for no buffering is the increasing speed electronics at communications media relative to the electronics at communications nodes. The “田” network algorithm implemented at each node must be simple enough so that the nodal electronics does not become a performance bottleneck. The structure of nodes in this “田” network is shown in Fig.2.

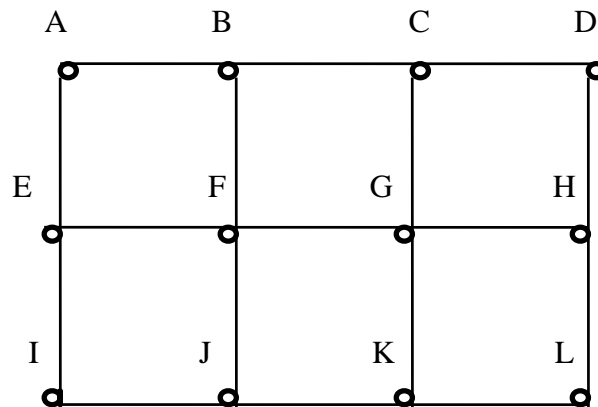


Fig. 2. The structure of nodes in “田” network

The network does not store-and-forward the data at intermediate nodes, but requires packets to be immediately forwarded. The switching and transmission

processes take place on a time-slotted basis. The node switches each of the input packets links. If the buffer for an output link is full ,and two input packets are destined for this link, one of the packets is forced to take other links. This because of buffer overflow, even if there is no buffer at the node. New packets from any node are only transmitted when there is an empty slot on its output link. The availability of empty slots decreases when the network becomes busy. Packets that are misdirected take a longer path to their destinations and prevent more new packets form entering the network.

### 3.2 The Flow of “田” Network

If there is a virtual circuit from source node S to destination node D by from M node like node A ,node B etc., we can get simple flow model, it is shown in Fig.3.

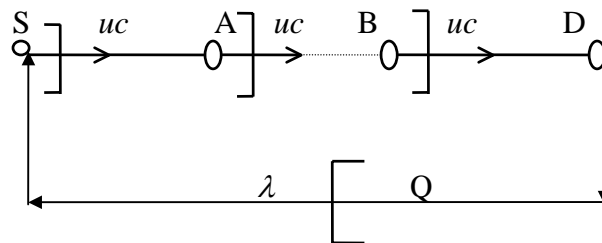


Fig.3 simple flow model

In Fig.3,  $\lambda$  means packets average arrival ratio, we also assume the sending packets per sec. of node S, node A and node B is equal to  $uc$ . We add a rank Q manual, and assume that its average service ratio is equal to  $\lambda$ . We can calculate the flow of the whole virtual circuit. We assume that Fig.3 M rank is equivalent to a rank, and the packets that will send of this rank is equivalent to the sum of packets of M ranks. The equivalent circuit is shown in Fig.4 .The average ratio of the equivalent rank is  $u(n)$ .

We can know:

$$u(n) = uc * P[\text{rank of node M is empty}] = uc * ( 1 - P[\text{rank of node M is not empty}] )$$

N packets distributing in M ranks have “get n from (n+M-1)” kinds of combination, the combination of node M is empty have “ get n from (n+M-2) ”

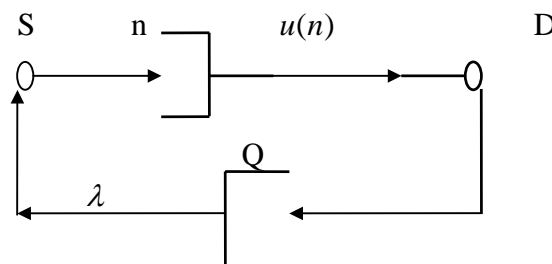


Fig. 4 equivalent rank of M ranks

kinds, so the ratio that node M is empty has:

$$P = \binom{n+M-2}{n} / \binom{n+m-1}{n}$$

$$= \frac{(n+M-2)!}{n!(M-2)!} / \frac{(n+M-1)!}{n!(M-1)!} = \frac{M-1}{n+M-1}$$

so :

$$u(n) = uc \left(1 - \frac{M-1}{n+M-1}\right) = \frac{nuc}{n+M-1}$$

so the flow of the whole virtual circuit is :

$$y = \sum_{n=1}^N u(n) p_n$$

$$p_n = p_0 \lambda^n / \prod_{i=1}^n u(i) \quad , p_0 \text{ is the ratio of the equivalent rank is empty.}$$

### 3.3 Distributed Routing Algorithm of “田” Network

In this section ,a distributed routing algorithm is described that uses the regular structure of the “田” network to select a path to the destination. We can get the delay time of certain node to all around node by sending “echo packets”, so we can get the optimal path to destination node according to the following equation:

	E	B	J	G
A	2	1	5	4
B	3	0	4	3
C	4	1	5	2
D	5	2	6	3
E	0	3	3	2
F	1	2	2	1
G	2	3	3	0
H	3	4	4	1
I	2	5	1	4
J	3	4	0	3
K	4	5	1	2
L	7	6	2	3

Table. 1 The p of node E、 J、 B、 G to any other node

$$p = t + a u(n)$$

p means the power value of optimization, t means delay time, u(n) means the flow of certain link. In “田” network, each node exchange signal with near nodes time and save a table which record the value p that it arrive every destination node. The network structure is shown in Fig. 2. We assume that the p of node E, node J, node B, node G arrive any other nodes is shown as Table.1 and the newest power value p from node F to node E,J,B,G is 1,2,2,1, we can get the optimal power value p from node F to every other node, then can get the optimal routing of node F, it is shown as Table.2 .

	A	B	C	D	E	F	G	H	I	J	K	L
new delay of node F	3	2	3	4	1		1	2	3	2	3	4
route	B or E	B	B or G	G or C	E		G	G	E or J	J	J or G	G or J

Table. 2 The optimal routing of node F

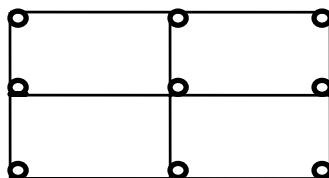
#### 4. THE CALCULATION OF RELIABILITY OF “田” NETWORK

The standard of the reliability of network means when network component including link and node have some trouble, the whole network still can communication without stop. We know only when the entire link of cut-set is broken, the whole network will be broken.

At first ,we assume that have a network structure shown as Fig.5,and the ratio of broken of every link is p. Node is source ,T is destination node. then the ratio of broken is :

$$P_{S T} = A p$$

Source node S



Destination node T

### Fig.5 Network Structure

$\theta$  means the numbers of link of the cut-set which include the least link.  $A_i$  means the numbers of cut-set which include I link.  $A_i$  is easy to calculate in simple network, but it commonly adopt  $C_m^i$  instead of in complicated network.

The network of Fig.5 include 12 links and 9 nodes. We know that the numbers of link of cut-set which have the least links is equal to 2, then we can get  $\theta$  is equal 2, and so we can calculate the ratio of broken:

$$P(S, T) = \sum_{i=2}^{12} A_i p^i (1-p)^{m-i} =$$
$$2p^2(1-p)^{10} + C_{12}^3 p^3(1-p)^9 + C_{12}^4 p^4(1-p)^8 +$$
$$C_{12}^5 p^5(1-p)^7 + C_{12}^6 p^6(1-p)^6 + C_{12}^7 p^7(1-p)^5 +$$
$$C_{12}^8 p^8(1-p)^4 + C_{12}^9 p^9(1-p)^3 + C_{12}^{10} p^{10}(1-p)^2 +$$
$$C_{12}^{11} p^{11}(1-p) + C_{12}^{12} p^{12}$$

If  $p$  is equal to 0.1, then  $P(S, T) \approx 0.025$ , that means if the broken ratio of BUS network or TREE network is 0.1, then the broken ratio of “田” is 0.025, so we can conclude the reliability of “田” network is four times over that of BUS network and TREE network.

## 5. CONCLUSIONS

This paper presents the optimal algorithms to improve the reliability for “田” network, which is distributed. Algorithm adopt delay time and flows as its optimal aim. We can conclude that the reliability of “田” network is four times over that of BUS network and TREE network by calculation. Further work can be initiated to a detailed queuing model for “田” network and to get more extensive simulation results for jam control and flow control in the whole network.

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