Research of the self-healing technologies in the optical communication network of distribution automation

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Abstract. Optical communication network is the mainstream technique of the communication networks for distribution automation, and self-healing technologies can improve the in reliability of the optical communication networks significantly. This paper discussed the technical characteristics and application scenarios of several network self-healing technologies in the access layer, the backbone layer and the core layer of the optical communication networks for distribution automation. On the base of the contrastive analysis, this paper gives an application suggestion of these self-healing technologies.

1. Introduction

Optical communication is the mainstream technique of the distribution automation communication networks. A typical network model of the distribution automation fiber-optic network for can be divided into 3 layers, they are access layer, backbone layer and core layer[1]. The access layer consists of layer 2 industrial Ethernet switches in the power distribution rooms, which form a hand-in-hand ring structure. The backbone layer consists of layer 3 switches in the transformer substations, the communication channels between the backbone switches can be directly connected optical fibers or SDH/MSTP networks. The core layer consists of the routers which connect the backbone layer and the master station server of distribution automation. This paper will analyze the self-healing technologies in different layers to improve the in reliability of the optical communication networks significantly.
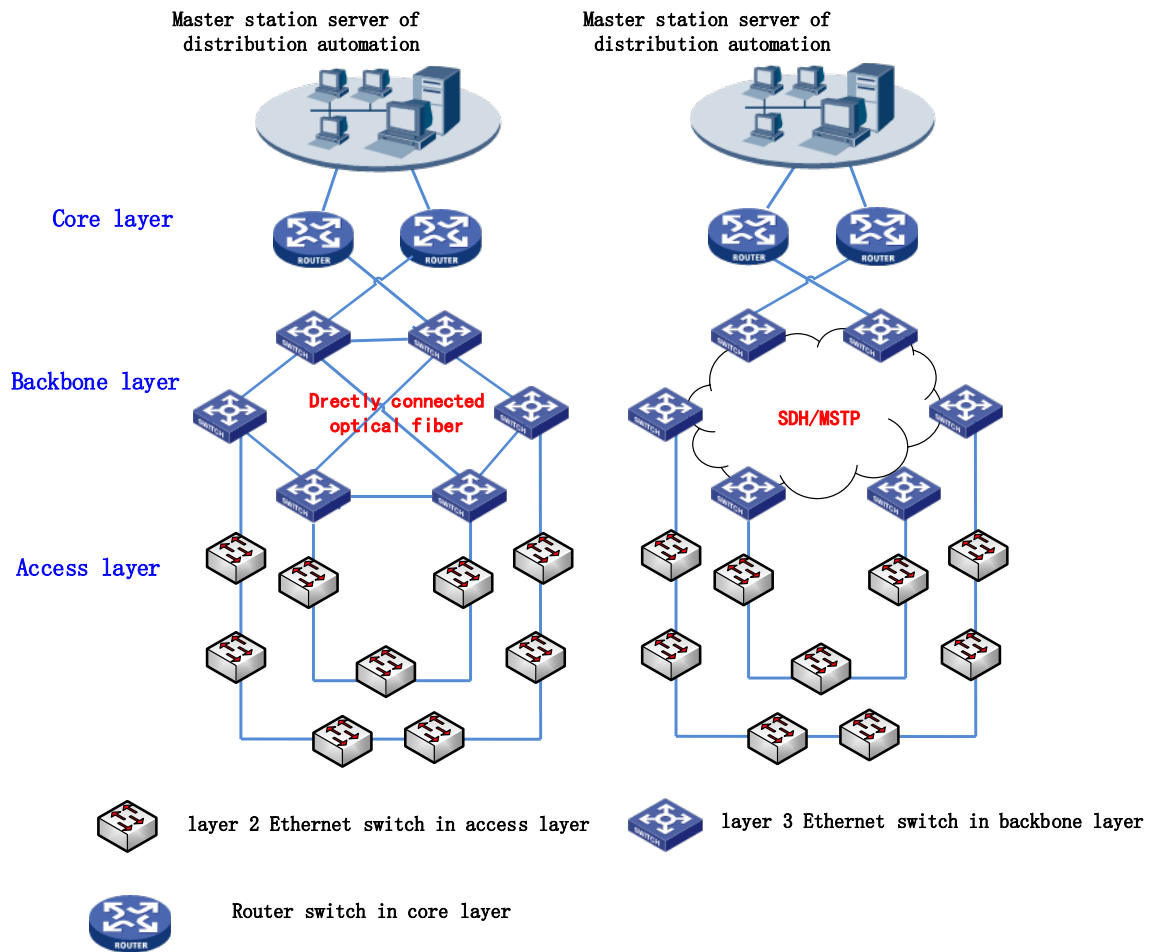
Figure 1. 3 layers structure network model of the distribution automation fiber-optic network.

2. Self-healing technologies in the access layer

The access layer of the distribution automation fiber-optic network is a layer 2 network which consists of the industrial switches, so the self-healing technologies in the access layer are mainly layer 2 protocols.

2.1. *The spanning tree protocols*

The industrial switches form Ethernet layer 2 hand-in-hand rings. The spanning tree protocols are widely used in these hand-in-hand rings to block redundant links to eliminate possible path loops and suppress the broadcast storms in Ethernet layer 2 networks [2]. When the current path fails, the spanning tree protocols will activate redundant backup link and restore network connectivity [3].

The STP protocol has slower convergence speed than RSTP. And the private spanning tree protocols (turbo chain, turbo ring, etc) cannot adapt to the interconnection of industrial switches from different manufacturers. So RSTP is the most suitable spanning tree protocol in the access layer.
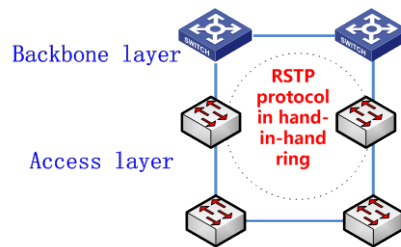
Figure 2. Use RSTP protocol for the self-healing of the hand-in-hand ring in the access layer.

2.2. The HSR protocol

RSTP cannot meet the demand of zero self-healing time. The convergence time will get longer when the number of the communication nodes increase. The convergence radius of the spanning tree exceed the limit of the protocol may cause broadcast storm.

PRP and HSR are two zero self-healing time redundancy communication protocols used in smart substations, which can also be used in distribution automation. The PRP protocol needs to build two independent communication networks, which will double the network construction cost [4]. Deploying the HSR protocol only needs to upgrade the boards of the industrial switches in the existing network. So HSR is more suitable to be used in the access layer of the distribution automation fiber-optic network. Several doubly attached bridging HSR communication nodes can form a typical HSR network [5]. In HSR networks, a frame is sent to two paths, the destination node will compare two received frames, and select only one, so the self-healing time will be zero when single node network failure happens. Figure 3 shows the transmit flow of a unicast frame in a HSR network.
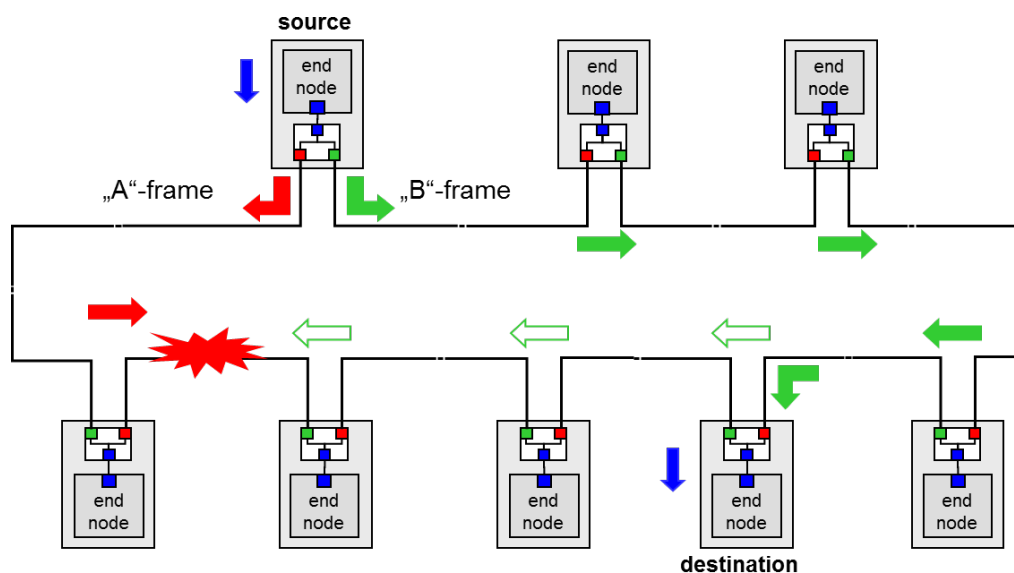

Figure 3. The transmit flow of a unicast frame in a HSR network.

2.3. Optical bypass protection

Optical bypass protection system can automatically bypasses the failed network nodes. The Optical bypass protection system can automatic identify the power supply status and optical signal output status of network nodes. When the node fails, the system will make the instantaneous switching of the optical path to bypass the failed network node to keep the optical communication system connected. Passive optical bypass equipment usually has lower cost than active optical bypass network, so it is

more suitable to apply in the access layer. Figure 4 shows the self-healing of the industrial switches in the access layer equipped with passive optical bypass equipment.
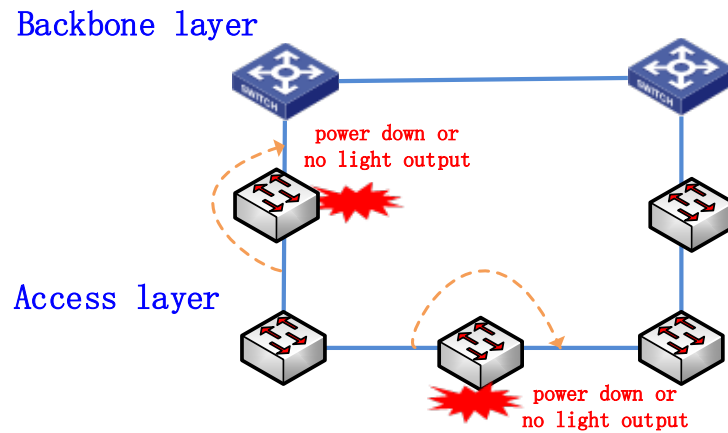
Figure 4. The self-healing of the industrial switches equipped with passive optical bypass equipment.

3. Self-healing technologies in the backbone layer and the core layer

The backbone layer and core layer of the distribution automation fiber-optic network are both layer 3 networks, so the self-healing technologies are similar in these two layers.

3.1. The VRRP protocol

VRRP (Virtual Router Redundancy Protocol) is a dynamic election protocol, which votes a Master router (Master) from a set of VRRP routers and associates the Master to a virtual router as a gateway to the network segment. Master bears the forwarding of the data packets, the other routers are in backup mode. When the Master router fails, the VRRP protocol will elect a new one from the backup routers to assure virtual routers are always at work. VRRP can avoid network failure caused by the failure of single LAN gateway. Figure 5 shows that configuring the layer 3 switches in the backbone layer in the transformer substations with VRRP can improve the in reliability of the network.
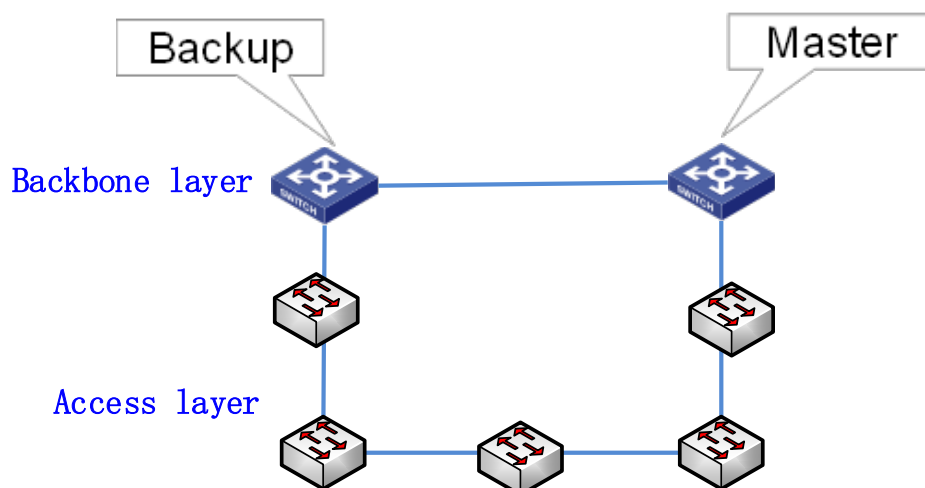
Figure 5. Configure the backbone layer switches in the transformer substations with VRRP.

3.2. The layer 3 routing protocol

Comparing with static routing protocol, dynamic routing protocols can automatically find routings and calculate routings. So the layer 3 networks in the backbone layer and the core layer of the optical communication network for distribution automation can use dynamic routing protocol to achieve self-healing after network adjustment.

RIP(Routing Information Protocol) is simple in principle and easy to configure. But RIP forwards data packets only based on hop counts, and it doesn't calculate the cost of different links, so it always cannot get optimal routings. Only support max 16 hops makes RIP cannot adapt to large scale networks.

OSPF(Open Shortest Path First) protocol is a routing protocol based on link state. OSPF only propagates the routing information which is not available to the remote devices, so it will make the network converges rapidly and effectively avoid the waste of network resources. So OSPF is a suitable routing protocol for the backbone layer and the core layer.

3.3. network protection technologies of SDH networks

When the communication channels between the backbone switches are SDH/MSTP networks, network protection technologies of SDH networks can improve the reliability. The mostly used protection technologies in SDH networks are two-fiber path protection ring and two-fiber bidirectional multiplexing section protect ring. The two-fiber path protection ring has quicker switching time, so it is more suitable for using in distribution automation, as long as it will cost more network resources.

After applying the two-fiber path protection ring, the backbone layer connected with SDH/MSTP networks will get higher reliability than directly connected optical fibers.

4. Conclusion

The access layer of the distribution automation fiber-optic network can use RSTP for self-healing. When higher reliability is required and the cost of network construction is not a key factor, the HSR protocol and optical bypass protection can be applied in the access layer. VRRP and OSPF can be configured to improve the reliability of the backbone and the core layer of the fiber-optic network. It is a better choice to plan the communication channels between the backbone layer switches with SDH/MSTP networks, because the investment of the construction of the optical cables will be saved and the SDH protection technologies will improve the reliability.

References

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