Ring Network Technology for Carrier Ethernet

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Abstract:
The fast development of IP services forces the traffic flow in the networks to move gradually from Time Division Multiplexing (TDM) services to packet data services. To adapt to the change, low-cost Ethernet technologies are introduced into the Metropolitan Area Network (MAN). Ring network control protocols and ring network protection technologies are applied to guarantee manageability and reliability required in the telecom networks. The Ethernet Ring Protection (ERP) and Resilient Packet Ring (RPR) are two different ring protection technologies. The Transport Multi-Protocol Label Switching (T-MPLS) network uses the T-MPLS Shared Protection Ring (TM-SPRing) technology to provide ring protection. Carriers can expand the protection as needed and use appropriate ring technologies to meet the requirements of Carrier Ethernet (CE).

The types of services carried by the telecom network have changed radically along with the acceleration of the IP service development. The primary service traffic is changed from Time Division Multiplexing (TDM) to packet. Because of the change of service type, there is a new requirement for the bearer network. The existing Synchronous Digital Hierarchy (SDH)/Synchronous Optical Network (SONET)-based transport network is suitable for constant-rate synchronization circuit services, but it is not quite suitable for the packet services with burst and uncertainty features, especially the large granularity data services (GE or 10 GE). Therefore, the problem is how to select a suitable packet bearer network technology to adapt to the tendency of IP traffic and provide the data service with available, effective and manageable service, which is the same as that for the traditional circuit service. This is a great challenge that carriers have to face in network construction[1].

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To ensure the competitive power for the Metropolitan Area Network (MAN), all the carriers are considering how to optimize or reconstruct the existing networks to meet the requirement of the new generation broadband subscribers. The broadband access, based on the Ethernet technology, with the feature of low-cost and the support for high bandwidth, has become a primary access solution for the existing MANs. The Ethernet technology is originally designed for the Local Area Network (LAN) use, with no consideration for any extension to MAN or Wide Area Network (WAN). But its ease-of-use and low cost make it widely applicable for broadband access. Therefore, all the world standardization organizations set to research whether the telecom-class features can be introduced to the existing Ethernet and thus implement end-to-end Ethernet services.

The so-called Carrier Ethernet (CE)[2] is to realize manageability and reliability in the Ethernet by adding transport network functions, expanding frame header or introducing Layer 2 protocols and signaling based on the frame structure of the traditional Ethernet. As a MAN Ethernet technology, Ethernet ring system solves the problems of the traditional data network such as low protection and slow fault resiliency. Theoretically, it can provide a feature of 50 ms fast protection. Meanwhile, it is compatible with traditional Ethernet protocols. Therefore, it is an important technical selection and solution for MAN network optimization and reconstruction.

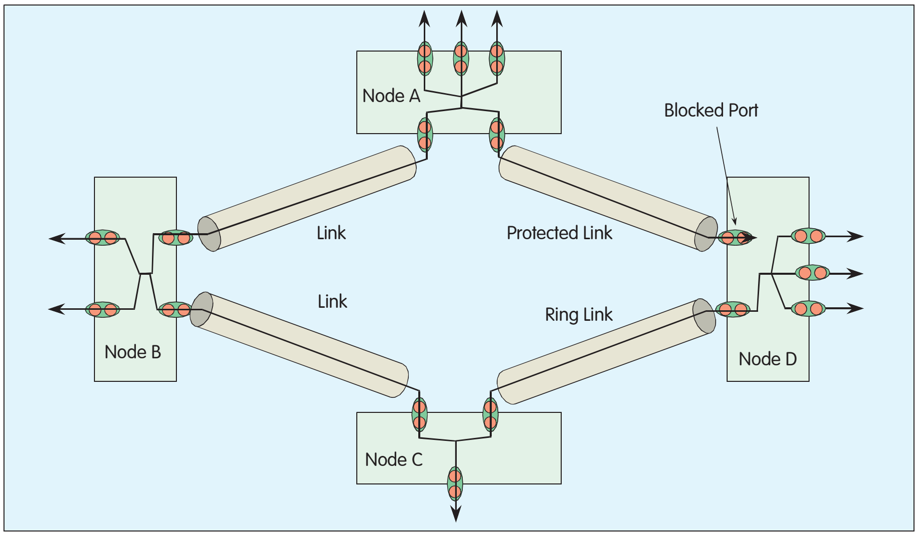
1 Purpose and Definition of CE Ring Networking

Ethernet uses Carrier Sense Multiple Access with Collision Detect (CSMA/CD). An Ethernet ring may cause broadcast storm, which makes the entire network full of data traffic and results in network breakdown. A tree structure is generally used in Layer 2 network construction because of this technical feature. Each node has only one unique uplink node, so the network will not become a ring, resulting in the fact that Ethernet has no ring protection mechanism. This makes it very difficult to achieve telecom-class reliability and availability. Ethernet ring technologies are generated based on the concept of SDH ring protection. The technical principle is to switch over to the standby link quickly using ring network topology upon device or link failure, with no affection on the running services. In the telecom field, the 50 ms level of fault resiliency can meet the requirement of service continuity.

ITU-T G.8032 provides a specific purpose and definition of the Ethernet ring networking[3-4]. It defines the Ethernet ring as a ring topology composed of a group of Ethernet nodes compatible with IEEE 802.1. Each node is connected to the other two nodes through the 802.3 Media Access Control (MAC)-based ring port. Ethernet MAC can be carried by other service-layer technologies (such as SDHVC and MPLS Ethernet pseudowire). All the nodes can communicate with each other directly or indirectly. Meanwhile, an Ethernet ring is both a physical topology and a logic topology, in which traffic flow is forwarded fully based on the forwarding rules of the IEEE 802.1 specification. It supports Ethernet services such as point-to-point (E-Line), multipoint-to-multipoint (E-LAN), and point-to-multipoint (E-Tree) services, including Ethernet Private Line (EPL) and Ethernet Virtual Private Line (EVPL). It supports various communications modes including unicast, multicast and broadcast, and can prevent data disorder and duplication. Ethernet ring supports three modes of ring interconnections: shared nodes, a link composed of two shared nodes, and multi-ring/layer network constructed by overlapped Ethernet networks. Services can be transported from end to end through interconnected rings.

2 Traditional CE Ring Protection Technology

It is often seen in actual applications that ordinary Ethernet switches are used to establish a ring-topology network, such as triangular and square topologies. However, these topologies are not ring technology. In simple words, ring network is the basis and prerequisite of the ring technology. Besides physical ring topology, the devices using the ring technology also supports ring control protocols. For example, when switches are used to establish a square network, the network is only a ring topologically, but generally it does not use any ring technology or protocol. The devices' forwarding and other operations are not different from the mesh network, so such networking is not a ring technology. Only the ring-topology network using a ring control protocol is a ring technology.



▲Figure 1. ERP ring architecture.

There are two classes of CE ring protection technologies: Ethernet Ring Protection (ERP) and Resilient Packet Ring (RPR). All the existing Ethernet ring technologies meet carriers' requirements for network performance through relevant technology expansion.

2.1 ERP

The ERP technology is a link layer protocol for Ethernet ring only. It prevents data ring from generating broadcast storms in the Ethernet ring. When a link or device on the Ethernet ring fails, it can be switched over to the standby link quickly to ensure fast service recovery. The fast fault resiliency principle of the ERP protocol is to transfer ring control messages through the private controlling Virtual Local Area Network (VLAN) inside the ring. Meanwhile, with the topological features of the ring itself, it discovers network failures quickly and switches the active link over to the standby one for fast recovery[5-6].

Different from other protection mechanisms, ERP provides protection for multicast services without the need of allocating additional capacity on the ring. All the capacities on the ring can be used to carry the protected multicast traffic.

According to the current Ethernet ring protection switching protocol (G.8032/Y.1344), the ERP technology needs to configure the main control node in each ring before working, with other nodes as transport nodes. The main control node can detect rings quickly by sending and receiving relevant protocol frames. According to the shortest delay principle, it selects a ring port from a node on the ring and sets it to the blocked status[7]. Node D in the ERP ring architecture depicted in Figure 1 is set to the "Blocked" status, while the ports of other nodes on the ring are set to the forwarding status. The blocked port processes only relevant protocol messages that use the Lightweight Distributed Ethernet Protection Algorithm (LDEPA) and discards other data and control messages, thus disconnecting the ring logically and solving the problem of broadcast storm on the ring.

When a link on the ring fails, the transmission switch detects the link failure and immediately sends a message to the primary switch. The primary switch unblocks the blocked port immediately to rapidly recover data forwarding. Other nodes on the ring clear the forwarding address table when they receive a failure notification message. If the node has a blocked port on the ring, it sets the port to the forwarding status.

When the failure is recovered, the node that discovers the failure recovery confirms the recovery through the waiting recovery time, and then notifies a failure recovery message to the two sides of the ring, and keeps the port connected to the failed span to the blocked status.

2.2 RPR

The RPR technology is a MAC layer protocol defined in IEEE 802.17 for optimizing data service transmission in a ring architecture[8]. It can adapt to multiple physical layers (such as SDH, Wavelength Division Multiplexing, and Ethernet) and transmit multiple types of services effectively, such as voice, data and video. RPR defines a brand new frame structure[9], which is a two-layer MAC address. RPR frame allows RPR to be a ring protocol and technology by adding special fields such as Time-to-Live (TTL) and Control-related ring control fields. The RPR MAC protocol is also different from the ordinary Ethernet. Besides using external MAC addresses (for identifying ring node devices), RPR switching also uses TTL, Control and other fields to select rings and check frame TTL. RPR also defines an independent and sophisticated Operation, Administration and Maintenance (OAM) frame and protocol for the RPR technology only, which are used for topology discovery, fault detection, performance detection, and fairness control.

RPR has a bidirectional dual-ring topology. Each segment of optical channel on the ring works at the same rate. The difference is that both rings of the RPR can transmit data. The two rings are called Ringlet 0 and Ringlet 1. Ringlet 0 transmits data in the clockwise direction and Ringlet 1 transmits data in the counter-clockwise direction.

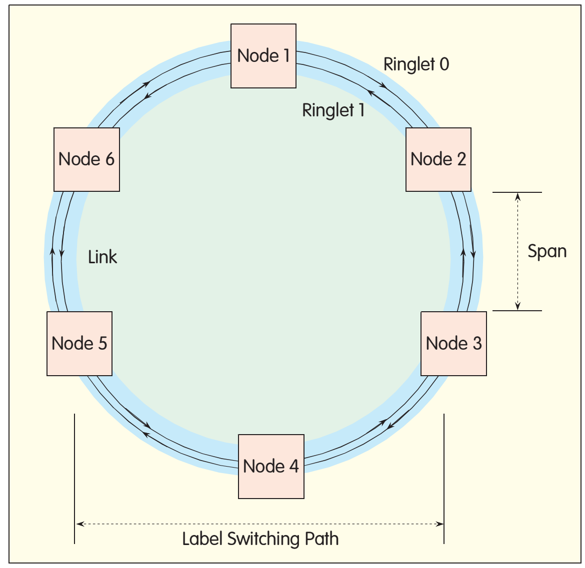
Each RPR node uses a 48-bit MAC address, which is used in the Ethernet, as an address ID. Therefore, the two pairs of sending/receiving physical optical interfaces are only a link layer interface as viewed from the link layer of the RPR node devices. As viewed from the network layer, only one interface IP address is required. The link between two adjacent RPR nodes is called "span". Many continuous spans and nodes on the spans form a domain[10]. RPR uses an SDH ring architecture and has a very high capability of fault resiliency, which allows fault protection switching within 50 ms. When a link failure occurs, Ringlet 0 and Ringlet 1 are connected to each other inside the nodes on both ends of the failed link to form a new ring.

The above two ring protection technologies are mainly based on the traditional Ethernet. They ensure the telecom-class manageability and reliability of the Ethernet.

3 T-MPLS Shared Protection Ring

The Multi-Protocol Label Switching (MPLS) technology allows switching based on label. It also supports data service transmission. Transport Multi-Protocol Label Switching (T-MPLS) is a unified multi-service transmission technology that meets telecom-class requirement based on the inherited MPLS data features. T-MPLS based ring network is also called T-MPLS Shared Protection Ring (TM-SPRing)[11]. T-MPLS ring protection is a technology that provides fast service protection in TM-SPRing.

T-MPLS ring is a T-MPLS LSP transmission ring constructed through logic structure mapping. All the nodes in a TM-SPRing establish logical adjacent relationships. Connection relationships are established without any restriction of physical devices or MAC topology. The connection between two adjacent nodes is called span. In a T-MPLS ring, span is a bidirectional connection that can be both physical and logical. The transport path entity for transporting services between ring nodes is realized by a group of T-MPLS based Label Switching Paths (LSPs). The ring bearer entity is in a dual-ring structure formed by one or more LSPs. The service traffic on the two rings runs in opposite directions, clockwise and counter-clockwise. According to the specific service direction, they can be divided into working ring (working service direction) and protection ring (opposite to the working service direction). Multiple LSPs can be established on each ring according to the number of services. Different LSPs are allocated for different service flow. TM-SPRing provides protection for the span between adjacent nodes. Service protection switching depends on the quality of signals in the span. Figure 2 illustrates the T-MPLS ring architecture.



▲Figure 2. T-MPLS ring architecture.

To prevent invalid span between adjacent nodes, a protection mechanism should be determined to provide fast protection in the case of failure. At present, two protection mechanisms are used in TM-SPRing: steering and wrapping. The steering mechanism allows the source node to change the path when a failure is detected. It bypasses the failed node and transmits data flow directly to the destination node. The wrapping mechanism allows the node near the failure to loop the data flow back to another ring. It allows the data flow to maintain the connection to the destination node by using a long path. The greatest difference between the two mechanisms is that the nodes that redirect data flow upon failure are different. The steering mechanism allows the source node to send data flow. The wrapping mechanism allows the adjacent node near the failure to redirect the data flow. The wrapping protection switch requires a short startup time, with fewer packets discarded, but the protected path to which it switches is not the optimal route. The protected path that uses the steering mechanism is the optimal route, but it requires a long switching startup time, with more packets discarded.

In T-MPLS SPRing, the Automatic

Protection Switch (APS) message achieves fault detection and protection switching by referring to the fast protection switching technology used in SDH. In normal conditions, a node without any fault reports its normal status to adjacent nodes, which are destination nodes. In case of a failure, the node that discovers the failure originates an appropriate bridging request in both directions. The purpose is to transmit information between the first and the end nodes switched in the wrapping mode, and to transmit the information of the failed span in the global network. The source node of the ASP information is the node that discovers the failure, and the destination node is its adjacent node, i.e., the other node of the failed span. All the non–destination nodes transmit APS information transparently. In the case when the failed span is invalid, the APS information between the source and destination nodes will pass through all the nodes on the ring. Each node processes the APS information and takes a switching action to achieve service protection on the ring.

The International Telecommunication Union Telecommunication Standardization Sector (ITU–T) is responsible for the T–MPLS ring protection scheme. It mainly uses the SDH function module protocol G.783 as a reference, but the standardization is not complete, and it requires further normalization of some issues (such as the source routing mode and mesh network expansion).

4 Ring Technology in MAN

In the MAN, ring architecture is mainly used for the transport network. Ring network topology has many advantages in layered networking, saving line resources (e.g., optical fiber and cable), providing fast and flexible protection, and simplifying network topology and network management. These advantages are not available in line and star networks. However, it must provide data channels with fast fault resiliency capabilities, in which the most important one is the protection switching within less than 50 ms.

At present, in the networks that are using various CE technologies, most of the vendors' devices support ring networking[12]. These technologies are largely similar with minor differences. They are ring network topologies physically and chain or tree topologies logically. The number of nodes on the ring is related to the device performance, traffic flow and transmission distance, but there is no restriction theoretically. Most of the existing ring technology solutions are expanded from the RPR or ERP technology based on the ITU–T Recommendation G.8032, for example, Multiple Super Ring (MSR), ZTE Ethernet Smart Ring (ZESR) and Ethernet–Shared Protection Ring (E–SPRing). The main differences include different fault detection approaches and the flexible selection of congestion points, which can improve the fault detection time and network bandwidth utilization. The TM–SPRing technology developed for T–MPLS will gradually be adopted by carriers along with the maturation and improvement of T–MPLS and the wide deployment of T–MPLS networks. TM–SPRing will be used to meet the requirement of CE reliability and manageability.

5 Conclusion

The first problem that needs to be solved for CE technology is high reliability. With the ring topology, CE allows fast and effective switch–over to the standby link without any impact on the services when a network device or link fails. The protection switching meets the requirement of 50 ms. Each Ethernet ring technology has its own emphasis. The ERP and RPR technologies are expanded according to the application demands to meet carriers' requirements. The TM–SPRing protection technology will also be widely researched along with the deep research and wide use of T–MPLS. Therefore, the usage and deployment of the technologies and devices of different vendors with the consideration of carriers' practical requirements are the most important issues for providing ring network protection for the carriers.

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