Technology Development and Deployment Strategy of Carrier Ethernet

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Abstract:
Carrier Ethernet (CE) is gradually stepping away from standardization and testing to deployment and application in live networks. Although great improvement has been made in the reliability of various CE technologies, there is need for improvement in their Quality of Service (QoS), Operation, Administration and Maintenance (OAM), especially the multi-vendor interoperability. The deployment of CE should be service-oriented, and the factors, such as maturity of related technologies and standards, deployment costs, and the complexity of network reconstruction as well as the interoperability with other vendors, should be taken into full consideration to flexibly select appropriate networking technology for different application scenarios according to technical features.

As IP technology is gradually replacing traditional technologies, the trend of a full IP network is irresistible. Enjoying the innate advantage of convergence with IP, Ethernet gradually goes beyond the applications within Local Area Networks (LAN) by virtue of its advantages such as better price-performance ratio per Mb bandwidth, simple management, flexible service loading, and low cost, and has become one of the leading networking technologies for Metropolitan Area Networks (MANs). On the one hand, the development of Ethernet technologies is reflected by the rate improvement from 10 Mb/s to 10 Gb/s; on the other hand, it is reflected by enhanced performance. New technologies for Quality of Service (QoS) guarantee, reliability and manageability are constantly emerging.

When applied into operators' networks, metro Ethernet technology has to meet the carrier-grade requirements. Currently, common Ethernet aggregation networks adopted by operators in broadband access networks of MANs cannot satisfy the requirements of NGN, IPTV and other high-quality services. Specifically, it cannot meet the requirements for reliability protection, and cannot provide good service management and network operation and maintenance owing to its poor Operation, Administration and Maintenance (OAM) capabilities; moreover, it is difficult to establish an end-to-end secured channel. In order to distinguish from traditional Ethernet applications and reflect the carrier-grade features, the telecom industry has proposed the concept of Carrier Ethernet (CE), which refers to metro Ethernet with scalability, QoS, reliability, security and manageability that can be used in operators' networks. Today, it has become one important task for operators to adopt CE networking technology to optimize their IP MANs for implementing their multi-service bearing capabilities.

1 Status Quo of CE Technologies

Driven by both the market and technologies, CE technologies and products are flourishing. Although there is a wide variety of CE technologies available, the grades of those devices are at different levels. The mainstream technologies include traditional Ethernet enhancement technology, Virtual Private Local Area Network Service (VPLS), Provider Backbone Transport (PBT), and Resilient Packet Ring (RPR).

1.1 Traditional Ethernet Enhancement Technology

The traditional Ethernet enhancement technology provides high reliability and scalability based on the optimization and improvement of traditional Ethernet architecture. It is characterized by no substantial changes in the interface and forwarding features of traditional Ethernet. The improvement and enhancement mainly occurs at the control layer to achieve carrier-grade protection. Traditional Ethernet enhancement technologies mainly include Ethernet ring technology, link protection technology, and Multiple Spanning Tree Protocol (M-STP). The traditional Ethernet enhancement technology can be implemented on the Ethernet switches in live networks by simple software upgrade, with no need of replacing devices in the live networks.

Ethernet Automatic Protection Switching (EAPS)[1] is an enhanced Fast Convergent Algorithm proposed for traditional Ethernet switches, and is mainly used in Ethernet ring topology. EAPS-based switches exchange Virtual LAN (VLAN) control messages to detect loop faults; the master node will conduct link switching once any faults take place. EAPS has Layer 2 protection mechanism for ring and mesh topology, and it offers VLAN protection. Moreover, it can provide recovery time of 100 ms while the fault detection is fully automatic without the intervention of OAM.

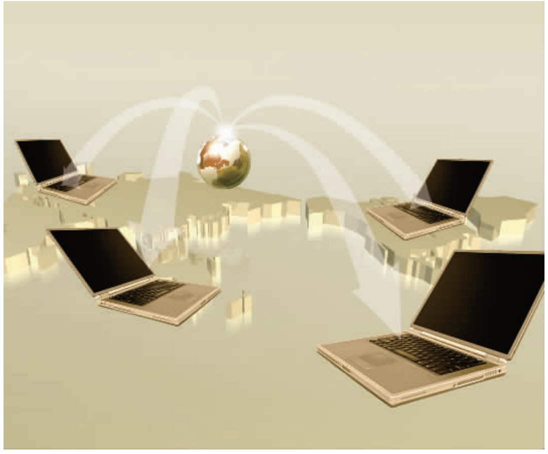
Although ring technology enhances network reliability, it still has certain weaknesses, such as a big number of times of remote node scheduling on the ring, and limited scalability. EAPS only supports ring networking, which restricts its flexibility. In addition, this technology, without fairness algorithm, is not suitable for broadband Internet access and other burst services with huge traffic, and may result in unfair occupancy of bandwidth among devices.

1.2 VPLS

Developed based on point-to-point Multiple Protocol Label Switching (MPLS), VPLS[2] is a Layer 2 Virtual Private Network (VPN) technology with multi-point interoperability; it expands Wide Area Network (WAN) MPLS to the access layer of Ethernet. From the users' viewpoint, it seems that all the sites are connected to one dedicated LAN. From the viewpoint of service providers, IP/MPLS infrastructure can be reused to provide various services. VPLS adopts two-layer MPLS label encapsulation, independent of specific physical topology, and it can support various logic topologies, so it has higher networking flexibility. In addition, the traffic engineering of MPLS can be used to optimize resources configuration. VPLS mainly has the following advantages:

- Fast Rerouting (FRR) technology, used to replace Spanning Tree Protocol (STP) and Rapid Spanning Tree Protocol (RSTP) protection of Ethernet, which improves the protection switching time up to 50 ms;
- The scalable Access Control List (ACL) capability and ACL control of every user that enable safer control and policy mechanism;
- Good Layer 2 Aggregation capability and ability to implement Hierarchical VPLS (HVPLS), which further enhances network scalability and allows the user number expanded to the million level;
- Ablility to differentiate and ensure different traffic flows of a user, and enable simple service configuration and fast service provisioning;
- A clear boundary between the operator network and the user network that makes it easier for management.

VPLS establishes signaling on Layer 2 devices by adopting complicated Layer 3 protocols, so it has higher equipment cost. Furthermore, it has more protocol stack hierarchies and more complicated operation configurations. Therefore, it is especially expensive for large-scale MANs with thousands of nodes to use VPLS. In addition, the adoption of dual MPLS labels increases protocol overhead, resulting in poor efficiency when forwarding small packets. However, for large-scale MANs with strong demands for new advanced services like IPTV, VPLS is still a forward-looking technology option, especially for the core network.



1.3 PBT

PBT[3] is the enhanced Media Access Control (MAC) in MAC technology. Defined in IEEE 802.1ah, MAC in MAC encapsulates carrier's Ethernet frame header into user's Ethernet frame, which enables each message to have two MAC addresses. The core network transfers traffic only according to the operators' MAC address. All the nodes, except for edge nodes, are not required to learn user MAC addresses, so the capacity requirement of MAC address lists is reduced. Moreover, two-layer MAC addresses give a clear boundary between the operator network and the user network, safe and easy for management. Based on MAC in MAC, PBT turns off the MAC learning function, and eliminates the broadcast function that may result in MAC flood and restrict the network scale. Moreover, it uses VLAN Identifier (VID) + MAC (60 bit) as the only global address. By introducing connection-oriented backbone network tunnel protection mechanism, PBT can configure backbone network tunnels through the network management and control console, which enables strict QoS, bandwidth reservation, and 50 ms protection.

PBT technology takes advantage of hidden MAC addresses of MAC in MAC, while it still has the following problems:

- At present, it does not support signaling, which can only be deployed by network management devices. Additional MAC header is required, so it has high cell overhead;
- It can only provide point-to-point services, and fails to support common point-to-multipoint services in Ethernet;
- It can only provide one-to-one path protection while the local repair functionin MPLS Traffic Engineering (MPLS-TE) is not introduced. It leads to the increase of protection paths in network, and the convergence rate cannot guarantee 50 ms once paths increase;
- This solution requires replacing all the devices in a live network. Moreover, its connection with Digital Subscribe Line Access Multiplexer (DSLAM) cannot be protected, so it cannot provide end-to-end protection.

1.4 RPR

RPR[4] is a new type of MAC technology standardized by IEEE 802.17 working group. It is a MAC protocol working in Open System Interoperability (OSI) protocol stack Layer 2, irrelevant of physical environment. It can run over Synchronous Optical Network (SONET)/Synchronous Digital Hierarchy (SDH), Ethernet and Dense Wavelength Division Multiplexing (DWDM) networks. RPR technology combines the reliability brought by SDH's self-healing function with the advantages of Ethernet including cost-effectiveness, broad bandwidth, flexibility, and scalability. Based on ring topology, it provides bandwidth management for data optimization and high performance multi-service transmission solution.

Currently, there are two types of PRP devices: pure RPR and MSTP devices with embedded RPR. Most leading optical communication equipment vendors in China choose to develop the Multi-Service Transport Platform (MSTP) with embedded RPR, few of which are put into application.

1.5 Technology Comparison

From the abovementioned mainstream CE technologies, it is easy to conclude that:

(1) In respect of reliability, all the leading CE technologies available can meet the requirement of 50 ms, and only the Ethernet ring protection technology fulfilled by software upgrade has the protection switching time of about 100 ms. However, the current services unnecessarily require strict 50 ms protection, for example, users are generally imperceptible to fault recovery of a voice service in 150-250 ms.

(2) In respect of QoS, except that VPLS and RPR have strict QoS guarantee mechanism, other CE technologies basically use priority guarantee mechanism such as 802.1P, which has no improvement in nature compared with traditional Ethernet. Moreover, it is another QoS guarantee solution to implement hierarchical QoS at the access point like Broadband Remote Access Server/Service Router (BRAS/SR), so as to reduce the requirements for QoS guarantee in CE.

(3) In respect of OAM, most CEs fulfill OAM management based on 802.1ag/ITU-T Y.1731. At present, VPLS and PBT take the lead in OAM implementation, but other CE technologies can only realize certain basic OAM, such as link detection.

2 CE Standardization and Products

Many international standardization organizations have carried out the work on CE standards from different perspectives.

ITU-T mainly focuses on the architecture of operators' networks, therefore, its standards about Ethernet technology and services emphasize regulating how to bear Ethernet frames over different transport networks, including SDH, Optical Transport Network (OTN), Asynchronous Transfer Mode (ATM) and MPLS.

Instead of defining Ethernet services, IEEE mainly focuses on standardization for Ethernet technologies. IEEE is working on Ethernet standards, including 802.1QVLAN, STP (802.1d, 802.1w, 802.1s), 802.3ad link convergence, 802.3ahEFM, and 802.17 RPR.

IETF mainly focuses on how to provide Ethernet services in packet networks. The IETF PWE3 working group is working on standardization for service encapsulation and service simulation analog. The L2 VPN working group is responsible for specifying implementation solutions for L2 VPN provided by operators, including Virtual Private Wire Services (VPWS) and VPLS.

The Metro Ethernet Forum (MEF)[5], as the chief standardization organization for CE, is mainly responsible for the following technology development tasks:

(1) Metro Ethernet architecture: MEF proposed metro Ethernet architecture independent of various technologies, and the reference point of User Network Interface (UNI).

(2) Metro Ethernet services: MEF defined the metro Ethernet service framework from user's perspective and specified service types.

(3) Metro Ethernet protection and QoS: MEF proposed protection modes, mechanism and QoS function framework for metro Ethernet, that is to say, it defined the QoS functions and characteristics required by executing and maintaining Service Level Agreement (SLA).

(4) Metro Ethernet management: MEF proposed the network management interface of metro Ethernet and formulated specifications for interfaces in network hierarchy, subnetwork partition, subnetwork topology and network connection.

With regard to CE products, most devices available support the abovementioned mainstream technologies. In addition, several vendors have launched distinctive CE products, among which VPLS is relatively mature, and these devices have small-scale deployments and applications in the networks of such operators as British Telecom and Southwestern Bell Corporation (SBC). At present, the Ethernet ring technology is not mature; although many switch vendors have launched IETF RFC 3619 on Extreme Networks' EAPS-based Ethernet ring devices, these devices cannot interoperate with each other because of different implementation methods used, such as different state machines, different frame formats and software/hardware implementation. Currently, operators and standardization organizations are actively promoting EAPS interoperability standards to solve the abovementioned problem. RPR technology is mature, but it gets less support from vendors.

At present, there is no big breakthrough in CE products in respect of QoS and OAM compared with traditional Ethernet switches. In addition, CE products cannot support circuit emulation well. Therefore, CE products are still not mature on the whole. Although various CE technologies can basically meet higher requirements on reliability, there is still need for improvement in QoS and OAM. Generally speaking, CE is undergoing tests in operators' networks worldwide, short of large-scale deployment cases.

3 CE Construction and Deployment Strategy

Currently, the competition among telecom operators has shifted from backbone network to MAN. It has become a common goal to construct metro transport networks that are cost-effective, highly efficient, and can support multi-service integrated bearing. It is an important issue for global operators to solve the problem of application and deployment of CE according to its characteristics and in light of the actual needs of the operators.

3.1 Driving Force: Service Development

For operators, service requirements guide their CE deployment. New multimedia services like Voice over Internet Protocol (VoIP) and IPTV require the metro broadband access network enhancing the following capabilities:

- Highly flexible scalability in bandwidth, capacity, and services;
- Fast protection recovery capability to meet the operating requirements of suchimportant service as Softswitch and IPTV;
- QoS guarantee for offering differentiated services from both dimensions of users and services;
- Strict traffic and service permission control capabilities to ensure safe operation of high-value closed services.

3.2 Starting Point: Network Reconstruction

Existing metro broadband access networks are short of resiliency and reliability, because of single node and single link faults in the star topology. Moreover, QoS and security mechanism of some devices in the networks still needs to be improved. To meet service requirements, operators should solve the following problems in their broadband access networks:

- Provide carrier-grade reliability and stability, troubleshoot single node and single link faults in the star topology, provide Layer 2 domain protection, and avoid multiple cascade as much as possible;
- Support multi-service deployment, improve QoS mechanism for QoS guarantee high-grade real-time services, and simultaneously offer differentiated services;
- Improve network manageability, provide abundant OAM measures, and reduce Operation Expenditure (OPEX);
- Enable high-bandwidth access to meet users' increasing demand for bandwidth.

3.3 Deployment Scope

Chinese operators generally have large-scale MANs, with BRAS/SR deployed at the lower layer. Therefore, for them, CE is positioned at the Layer 2 access and aggregation layer below the services access point. In the future, the possibility to use CE networking for the whole MAN with the maturity of technology remains.

3.4 Deployment Strategy

CE deployment basically aims to meet demands of users and services. It should take effort to improve network reliability, differentiated services and OAM capability, and fulfill service isolation and multi-service integrated bearing. Meanwhile, it should focus on implementing high-level QoS guarantee for both operators' self-operating transformation services and high-end VIP customers' access.

Under the prerequisite of meeting the requirements of service sustainable development, returns on investment should be taken into full consideration. CE deployment should be implemented in phases according to network situation, actual operation conditions and the development trend of broadband access network technology, so as to reach the goals of developing services, reducing network construction cost, and avoiding investment risks.

The selection of CE technology should take into full consideration the maturity of related technologies and standards, deployment cost, the complexity of network reconstruction, and the interoperability with other vendors. All the technologies have their strong and weak points, so the selection should be flexible according to different application scenarios. For example, VPLS can be applied at the metro core network to provide bandwidth services for VIP customers like metro VPNs; EAPS can be applied in ring topology to bear operators' self-operating key services with high requirements for reliability.

Among the CE technologies, the enhanced Ethernet ring solution based on traditional Ethernet technology greatly improves its fast protection switching and multicast duplicating, solves such problems as weak protection capability of traditional data network and long time for fault recovery, and can be implemented by the reconstruction of live networks with low deployment cost. Therefore, it is currently a feasible solution. However, there are still many problems to be solved, such as its unsatisfied QoS, OAM, circuit simulation support, and especially its failure to support the multi-vendor interoperability; it is a long way to fulfill its large-scale application. Operators shall actively promote the improvement of related technologies and interoperability with other vendors in light of their actual network and service demands.

4 Conclusion

Driven by both service and technology, CE has made great progress and become one of the leading technologies in MAN. It has the carrier-grade features, but it pays much for complexity and cost. CE needs technology optimization and standardization, so as to lay a solid foundation for large-scale applications in operators' networks.

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