Evolution of Optical Transport Networks and Their Solution in 3G Networks

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Abstract:
As new generation mobile networks, 3G networks focus on data services and integrate voice, data and multimedia services. However, traditional Optical Transport Networks (OTNs) cannot meet the requirements of 3G networks anymore, because of their complicated configuration, low bandwidth efficiency, high cost, and bad network and service scalability. The emerging of Multi-Service Transport Platform (MSTP), Wavelength Division Multiplexing (WDM), and Automatically Switched Optical Network (ASON) technologies for optical fiber communications makes up for these weaknesses. The leading solution to 3G access transport networks is the MSTP technology based on Synchronous Digital Hierarchy (SDH), while that to 3G core transport network is ASON+WDM.

As new generation mobile networks, 3G networks focus on data services and integrate voice, data and multimedia services. Since the 3G transport network is based on the Optical Transport Network (OTN), it has become a key research subject how the OTN provides 3G networks with an ideal transport channel.

1 Development and Evolution of Optical Transport Networks

In 1966, Dr. Charles Kuen Kao and George Hockham published the paper "Dielectric-Fiber Surface Waveguides for Optical Frequencies", which is regarded as the starting point of modern optical fiber communications. Over 40 years' development, new optical communication technologies[1], such as Multi-Service Transport Platform (MSTP) and Automatically Switched Optical Network (ASON), are emerging, following such digital transport systems as Plesiochronous Digital Hierarchy (PDH), Synchronous Digital Hierarchy (SDH). Generally speaking, technologies for OTNs have the following development trends:

- Convergence of transport and switching from the aspect of existing forms;
- All-optical networks from the aspect of hardware;
- Intelligent networks from the aspect of hardware.

1.1 SDH Network

The SDH network is a type of comprehensive data transport networks, which integrates multiple connections, line transmission and switching functions, and has a unified network management system. It fulfills multiple functions such as effective network management, real-time service monitoring, dynamic network maintenance and networking between equipment of different vendors.

SDH, based on Virtual Concatenation (VC), perfectly cracks the problem of Time Division Multiplexing (TDM) service bearing. However, since the IP telecom service bear is leading to a transport network more based on IP, the traditional SDH transport network becomes weaker in scalability and efficiency, because of its small scheduling granularity and limited transport capacity.

1.2 MSTP Network

Based on SDH technology, MSTP effectively integrates multiple technologies including Ethernet, Asynchronous Transport Mode (ATM) and SDH-based Packet over SONET/SDH (POS). By multi-service convergence and effective adaptation, it fulfills multi-service synthesized access and transport, and changes the SDH pure transport network into a multi-service platform integrating the transport network and the service network[2].

Essentially, MSTP technology implements SDH-based multi-service synthesized transport through encapsulating Ethernet data frames and ATM cells. Integrating TDM and Ethernet Layer 2 (L2) switching, it uses the L2 switching to fulfill intelligent data control and management, optimizes data transport in SDH channels, and solves the following problems:

- Signal service and fixed bandwidth of Add/Drop Multiplexer (ADM) and Digital Cross-Connect (DXC) equipment;

- High price of ATM equipment;
- Limited networking capability and bad Quality of Service (QoS) of IP equipment[3].

MSTP greatly enriches interfaces of the OTN, enables prompt access to multiple services like voice, data and multimedia. Moreover, it offers convergence and exchange functions on the data layer, which makes the optical transport network more convenient and more efficient for use. However, MSTP after all comes from SDH, not all-IP based. It makes the improvement only at the user interface side, but the core network side is still circuit structured. Therefore, MSTP also fails to offer enough scalability and efficiency to broadband IP services that have increasing requirements on wider bandwidth and bigger granularity.

1.3 IP over WDM Network

Since the traditional SDH network has deficiencies in scalability and operation, it has become a tendency to construct a flat architecture with direct optical-layer IP bearing. In the IP over Wavelength Division Multiplexing (WDM) architecture, the WDM layer is responsible for SDH's functions such as networking, and end-to-end circuit monitoring, management and protection.

IP over WDM technology, a solution to IP service bearer, has the following advantages:

- Large transport capacity;
- Long transport distance;
- Simple network structure;
- Rich service types born;
- High reliability.

This technology mainly fulfills multi-service access for the services like IP, ATM and TDM, and supports long-distance and large-capacity transport. However, with the convergence and development of IP data network and transport network, the IP over WDM technology is facing the problems of rapid network rerouting, dynamic service bandwidth allocation, and IP service performance detection.

The Multi-Protocol Label Switching (MPLS) technology has been introduced into the IP over WDM network to solve its problems. MPLS is a data-carrying mechanism that integrates L2 switching and Layer 3 (L3) routing. It can not only support multiple network-layer protocols, and also be compatible with multiple link-layer technologies[4].

1.3.1 T-MPLS Technology

Transport Multi-Protocol Label Switching (T-MPLS), a subset of MPLS, is a connection-oriented packet-switched application. T-MPLS maps signals into MPLS frames in the transport network, and transfers them by the MPLS mechanism (such as label switching and label stack). It selects and uses the MPLS characteristics that are good for data service transport, while discarding or simplifying complicated control protocol suite and data plane in MPLS. As a middle adaptation layer, T-MPLS can support both L3 IP packets and L2 data services. Its connection-oriented feature can fully ensure QoS requirements of upper-layer services. Moreover, it enables operation independent of the service layer and the control layer.

With T-MPLS, future core bearer network can be simplified into the combination of one pure optical fiber layer and one circuit layer. T-MPLS system is expected to become the service bearing platform that integrates IP network and transport network. Therefore, it has been a promising IP over WDM solution.

1.3.2 GMPLS Technology

The T-MPLS network consists of pure Packet Switch Capable (PSC) nodes, while the transport network is just treated as a pre-configured physical line. The PSC nodes are not able to adjust the physical line resources within the transport network to follow resource demands, and internal circuit allocation of the transport network can only be configured manually. Legacy MPLS system needs extension and update to meet the requirement that future intelligent optical network can dynamically offer network resources and transport signaling.

The Generalized Multi-Protocol Label Switching (GMPLS) technology is a product of MPLS's extension to the optical network. Besides PSC nodes, GMPLS also supports TDM nodes, Lambda Switch Capable (LSC) nodes and Fiber Switch Capable (FSC) nodes. Moreover, GMPLS makes extension and modification of the routing and signaling protocols in T-MPLS. A PSC node in the GMPLS network can, if necessary, build a circuit, wave channel or even fiber for its connection to other PSC nodes. What it needs to do is just to initiate a GMPLS signaling procedure[5].

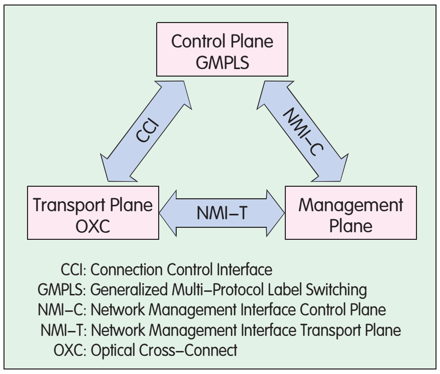
GMPLS makes IP network management and transport network management no longer separate. Therefore, it brings a bright future for the seamless convergence of IP network and optical network.

1.4 ASON

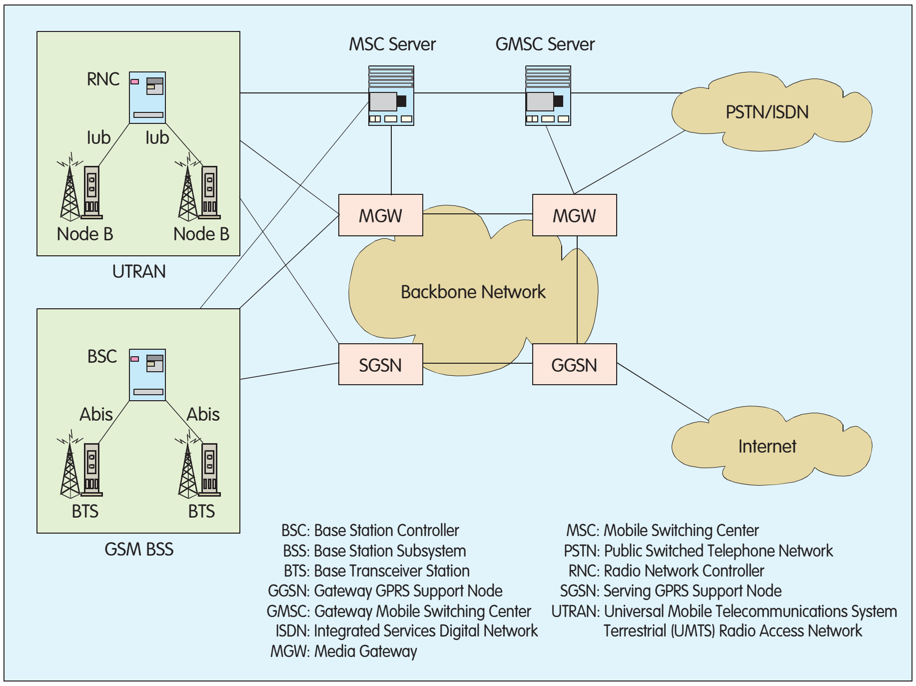
With the development and extensive application of WDM technologies, data traffic in the Internet is no longer limited by the capacity of transport lines; but the optical fiber circuit switching at network nodes is still its "electronic bottleneck". In fact, such switching at network nodes is unnecessary in most cases[6]. Therefore, optical network nodes should, just like IP routers, be intelligent to eliminate the "electronic bottlenecks".

ASON is a product of the development process of optical transport networks toward intelligent networks. In ASON, an intelligent control plane is introduced into the OTN to implement such functions as automatic routing discovery, call connection management and protection recovery. In this way, ASON enables dynamic call connection management. GMPLS is the best core protocol for the ASON control plane.

According to the ITU-T G. 8080 (G.ason) recommendations, ASON can be divided into three layers: the transport plane, the control plane, and the management plane, as shown in Figure 1. The control plane controls



▲Figure 1. ASON architecture.



▲Figure 2. 3GPP R4 architecture.

connection establishment, connection deletion and other operations. The transport plane is responsible for data service transport. The management plane fulfills the maintenance function of the transport platform, the control plane and the whole system, and it is network administrator oriented and responsible for coordination and cooperation between the planes.

The control plane implements its control on the transport plane through interacting with GMPLS protocol signaling. Used for data transfer and transport, the transport plane is an Optical Cross-Connect (OXC) equipment based WDM network. The management plane not only manages network devices, but also provides functional supplements to the control plane.

Since ASON can be fulfilled either based on the G.803 SDH transport network, or on the G.872 optical transport network, there are two networking solutions for ASON:

(1) ASON+WDM

This solution makes full use of the large-capacity long-distance transport capability of WDM system and the bandwidth capacity and flexible scheduling capability of ASON nodes. It is a network with powerful functions.

(2) ASON and SDH Hybrid Networking

This solution shows the evolution of the convergence between ASON and existing telecom networks. The networking starts from building multiple small ASONs in the existing SDH networks, and then gradually forms a big integrated ASON[7].

ASON well integrates the intelligence of IP transport network and the broad bandwidth of WDM optical network. It uses the broad bandwidth to offer large transport capacity, while with the intelligence of IP transport network it enables seamless connection with circuit-layer devices. According to its features, ASON can serve as both the bearer network and the service network. As the bearer network, it can offer reliable transport service to 3G service networks. On the other hand, ASON, as the service network, can directly provide subscribers with new services like high-quality private lines, Bandwidth on Demand (BoD) and Optical Virtual Private Network (OVPN).

2 Solutions for Optical Transport Network in 3G Network

WCDMA, TD-SCDMA, CDMA 2000 and WiMAX are all the standards for 3G system. Both specified by 3GPP, WCDMA and TD-SCDMA are resembled in network architecture, but different in air interfaces.

In the 3GPP R4 architecture shown in Figure 2, the Mobile Switching Center (MSC) server implements the processing of signaling and calling control; the Media Gateway (MGW) provides voice flow processing and interconnection of external networks; the Serving GPRS Support Node (SGSN) implements packet sending, receiving and relevant controlling between terminals and the Gateway GPRS Support Node (GGSN); the GGSN is the gateway for connection with external packet switching networks; and the Radio Network Controller (RNC) controls Nodes B, and provides users with the transport path from air to the core network[8].

The 3G transport network can be divided into the access transport network and the core transport network. The former is responsible for service access and transport between RNC and Node B, and the latter for transmission among RNC, MSC server/MGW, Gateway Mobile Switching Center (GMSC) server/MGW, SGSN and GGSN. Since RNC generally shares the same address with the core network node, it is deployed in the core transport network.

2.1 Solution for Access Transport Network

The SDH-based MSTP technology is recommended as the main solution for the 3G access transport network in this paper.

The SDH-based MSTP technology inherits the strengths of legacy SDH networks like clear network structure, convenient management and maintenance, and strong self-healing ability of services. Besides, if used as the access transport network, it has the following advantages:

(1) It needs a small investment for an operator to upgrade its legacy SDH network into a MSTP network, because most SDH optical transport devices working in live networks are able to smoothly evolve to MSTP. Moreover, compatible with SDH, the MSTP platform can combine with SDH system in live networks to form a unified basic transport

network platform, which can not only protect previous network investment of operators, but also fulfill unified maintenance and management of transport networks[9].

(2) The MSTP platform supports Virtual Path (VP) ring. The VP ring technology allocates a fixed bandwidth to multiple nodes on the ring, and the nodes can use the bandwidth according to their demands[10]. Although the 3G transport network always faces burst data and unbalanced traffic, the VP ring technology can help the MSTP platform to greatly improve bandwidth efficiency and reliability.

(3) The MSTP platform can carry diversified services. Besides meeting the transport requirements of 3G services, it can transport 2G and data services, and also support the VIP private line service and Optical Virtual Private Network (OVPN) value-added services. Therefore, it can fully present the value of resource networks.

(4) MSTP equipment can also support the MPLS technology, facilitating the IP bearer of 3G services in future 3G transport networks. Aiming at broadband data oriented 3G radio networks, MSTP is able to offer perfect upgradeable solutions.

(5) MSTP equipment can flexibly configure its TDM/ATM/IP module according to the amount of service traffic at different 3G phases, fulfilling smooth evolution from small to large service capacity, and from multiple services coexisting to all packet services. Therefore, it helps to decrease cost for network construction.

In general, it is a good networking solution to use SDH-based MSTP technology to build a 3G access transport network platform. It simplifies transport equipment structure, and fulfills the separation of the transport network and the service network with a clear boundary. In addition, it saves cost for network construction, and meets the tendency of the 3G transport interface toward the IP interface.

2.2 Solution for Core Transport Network

The ASON+WDM network is recommended as the solution for the 3G core transport network in this paper.

This is an ideal solution because the network has both the intelligence of the IP transport network and the broad bandwidth of the WDM optical network.

The 3G core transport network features in the IP-based and big granularity are becoming more prominent, which directly pushes the toll transport network to evolve from SDH to IP over WDM. However, there are plenty of IP packets in the IP transport network, and they require multiple routers to implement the conversion between their sources and destinations. This generates a large amount of direct-connection services. The IP over WDM solution asks routers to deal with these IP direct-connection services, which brings heavy pressure to the core router, and may generate extra cost[11]. Since ASON uses OXC-based all-optical switching, it can greatly alleviate the pressure of IP routers from large service processing capacity and capacity expansion, which further saves the overall network investment.

With the OXC-based all-optical switching of ASON, the optical signals of direct-connection services make routing at the optical fiber layer. This can decrease signal latency and jitter caused by IP routers to an utmost extent, which is good for QoS guarantee.

With the launching of 3G mobile services, operators have to change their network facilities, and the number of E1 and Synchronous Transport Modules (STM) 1/16 will definitely increase, especially at the gateways/core nodes for convergence, resource sharing and interworking with other operators' networks. Current manual configuration and operation of transport resources is extremely inflexible and expensive. However, the introduction of OXC-based ASON at the core node will obviously decrease cost for elastic service provisioning, equipment maintenance, and line hiring. Moreover, ASON can offer new services like OVPN, enhanced private line service and BoD service.

Besides, ASON supports mesh networking, and has mechanism for rapid and effective network protection and recovery, giving the transport network strong viability[12].

Generally, with the development of IP-based and large granularity 3G networks, the ASON+WDM core transport network will be a superior solution. It complies with the entire development trend of optical transport networks.

3 Conclusion

The optical transport network and communication networks have been adapting to and promoting each other during their development course. Pushed forward by the development of IP-based 3G networks, the optical transport network is evolving to the packet transport network based on optical fiber. Its development goals are intelligence, high rate and large capacity. Conversely, the development of optical transport technologies greatly supports the development of 3G networks.

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Biography

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Zhang Bo received his master's degree from Automation Department of Northwestern Polytechnical University. He is an engineer of ZTE Corporation, engaged in system testing of 3G CS domain core networks.