Advances in DWDM Optical Networking Technology

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Abstract：Wavelength routed Optical networking technology is the certain technology for future transport network upgrading because of its potential cost-effectiveness, large capacity, flexible reconfiguration and strong survivability, it has been flourished all over the world. Many achievements in this field have been obtained due to the hard work of the related engineers all over the world. The implement and thriving of commercial Optical Internet is just a problem of time. In 1998, a four-node all-optical metropolitan self-healing ring testbed called SHAONet (Shanghai All-Optical Network testbed) have been established in Shanghai Jiao Tong University for the first time in China. It brought about the development of optical networking technology in china, and the achievement has shorted the gap between China and advanced countries in the field of optical networking technologies.

Key words: DWDM optical networks, OADM, OXC, IP/DWDM, all-optical metropolitan self-healing ring

Today, with the exploding of Internet, Intranet and e-commerce applications, every major service provider worldwide is facing the formidable bandwidth challenge of designing or evolving their core network architectures. The development of current telecommunication service needs broadband optical transport networks with cost-effectiveness, large capacity, high flexibility and strong reliability. What will it take to create a network that fits this demand?

Today's transmission network of the existing public network consists of three primary components： Fiber cable that provides raw capacity, Dense Wave Division Multiplexing (DWDM) using *virtual fiber* technology by dividing a fiber strand into multiple wavelength Channels， and SONET/SDH transmission equipment converts data traffic from an electrical signal to an optical signal for transport over the fiber network and provides the traffic monitoring/management. However, in SONET/SDH based transmission network, the fiber and DWDM equipment provide nothing more than a physical transmission medium. While the transmission of traffic and the scaling of capacity are performed in the optical domain, access, regeneration, switching and routing are performed in the electrical domain, requiring expensive equipment to transfer from one domain to the other. As the number of wavelength increases, the complexity escalates. Practically, only 25-50% incoming traffics need to be dropped and processed at arbitrary nodes. So, at least half of incoming traffics need not to be processed with time-consuming and expensive electrical equipment. With the traditional 100% electrical equipment redundancy protection mode, the cost is needless high.

The broadband optical networks which employing wavelength-routing technology has been demonstrated to be the most promising means to economically satisfy the rapid growing demand of bandwidth. By means of Optical Add-Drop Multiplexer (OADM), Optical Cross Connect (OXC), as well as corresponding network management system, the incoming high data rate traffics can be transmitted, switched, routed and restored dynamically in optical domain. This can overcome the capacity battle-neck and decrease the abundant capacity of pure electrical switching, and increase the flexibility of network reconfiguration greatly. With the exploding development of Internet, IP will be the best candidate for integrating data communication and telecommunication in the future. Therefore, the technologies that once supported the backbone of the voice-centric public network are now undergoing critical evaluation and rapid change, wavelength routed DWDM optical transport networks suitable for IP transmission will be the necessity of future broadband communication networks.

With the emergence of super high-speed interfaces and the mature of high-speed electrical IP routing switches, as well as the future ultra-high-speed optical packet switches (also called optical IP router), current layered optical networks employed technologies of IP/ATM/SDH/DWDM、IP/ATM/DWDM、IP/ SDH/DWDM will upgrade to ultra-high-speed IP/DWDM optical networks. But this trend does not mean that the ATM and SDH equipment will be discard wholly, they will find their places in the edge of the backbone networks.

Future large-scale DWDM optical transport networking will not be a ‘complete transparent’ one as people used be taken for granted, it is ‘opaque’ from source to destination. The reason is the network performance degradations due to following causes as chromatic and polarization-mode dispersion, polarization-dependent loss, multipath interference, the noise accumulation, optical-fiber non-linearities, and wavelength-misalignment etc. O/E/O transponders must be involved into the optical network nodes to perform the functions as ‘3R’ and wavelength matching etc. However, the small-scale networks or sub-networks can be transparent.

Since 90’, Northern American, European Union and Japanese have implemented and are carrying out a number of projects related to optical networks, such as AON, ONTC, MONET, NTON, MWTN, PHOTON, OPEN, METON, WOTAN, MOON, etc. Several field trials have also been established. Though many of the abuilding and planing commercial Internets are claimed to be based on technologies as IP/SDH/DWDM and IP/DWDM, in fact, the node switches are still pure electrical ones. However, in current, the newly planing DWDM optical networking projects are mostly IP optimized optical transport networks such as NGI (Next Generation Internet) in USA and CANARIE*3 in Canada. They will be finished about 2002.

In 1995, Shanghai Jiao Tong University had proposed carrying out all-optical networking technology in China, and obtained the support of National 863 plan. From then on, China has began its National supported development of all-optical networking projects, and the Chinese backbone has also began her upgrading course from ‘single-fiber single-wavelength channel’ plus ‘pure electrical switch’ to ‘DWDM transmission’ plus ‘pure electrical switch’ to ‘DWDM transmission’ plus ‘optical/electrical mixed switch’.

In August 1998, a three-node (three OADMs) all-optical metropolitan self-healing ring test-bed named SHAONet—Shanghai All-Optical Network have been established at the Center for Broadband Optical Networking Technology (CBONT) in Shanghai Jiao Tong University. In December 1998, the three-node all-optical metropolitan self-healing ring test-bed has been upgraded to a four-node all-optical metropolitan self-healing dual-ring test-bed. To our knowledge, they are the first operational all-optical metropolitan self-healing rings and dual-ring test-beds with complete network layers (application layer, electrical layer and optical layer) in China. See figure 1. The success of SHAONet has greatly pushed the development of broadband optical networking technology in China.

In 1999, National Nature Foundation has started its core project called ‘Study of WDM all-optical networking basal technologies’. In the mean time, National 863 Plan has also united its main sources from the fields of communication, computer and optoelectronics, are planing for a project called China Advanced Information & Optical Network (CAINONET), optical networking is the key technology in this project.

The features of SHAONet are as follows: (1) It possesses complete configurations as optical layer, electrical switch and application layer. (2) It employed the IP/ATM/SDH/DWDM technology. (3) Six wavelengths within ITU-T grids can be operated and add/dropped dynamically, the wavelength spacing is 400GHz. (4) The spacing between adjacent nodes is 50km, the total distance is 250km. (5) The network is managed by network element management and central management that perform the network configuration, performance monitoring and failure restoration management in optical layer. (6) Several novel OADMs have been demonstrated, and the functions of protection and wavelength routing are separated. (7) Two kinds of OXCs have been demonstrated, one is for the connection of self-healing ring (SHR-OXC), the other is for the connection of ring, mesh and linear networks (RML-OXC). (8) It possesses the functions of network self-healing and failure node isolation, the measured restoration time is less than 4ms. (9) The data rate of each wavelength channel is 155Mb/s or 2.5Gb/s, and the BER fitted for the standard of ITU-T. (10) Broadband services as VOD (Video on Demand), multi-point multimedia TV conference and data transmission have been operated in the testbed. Table.1 is a summary of the features of SHAONet.

In summary, broadband optical networking technology has been flourished all over the world because of its large capacity, flexible reconfiguration and strong survivability, and it is the certain technology for future network upgrading. Many achievements in this field have been obtained due to the hard works of the engineers all over the world. The implement of DWDM commercial Optical Transport Networks is just a problem of time. In China, a four-node all-optical metropolitan self-healing dual-ring testbed called SHAONet have been established at Shanghai Jiao Tong University for the first time in 1998. It brought along the development of optical networking in china, and the achievement has shorted the gap between China and advanced countries in the field of optical networking technologies.

Fig.1 Photograph of the nodes of SHAONet

Table.1 a summary of the features of SHAONet.

Items	**Values**	**Items**	**Values**
Node equipment	*OADM/OXC*	Wavelength routing	*Dynamic*
Network topology	*Unidirectional two fiber ring*	Network survivability	*Self-healing*
Node number	*3/4*	Style of restoring	*Link breaking protection/ node failure separation*
Wavelength number	*6*	Experimental circumstance	*Show room*
Channel spacing	*3.2 nm*	Total ring length	*150/250 km*
Bit rate of each channel	*155 Mb/s-2.5 Gb/s*	Spans between nodes	*50km*
Recovery time	*Less than 4ms*	Test services	*Data transmission, VOD and TV conferencing*

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