Optimization Technology of Optical Fiber Communication Network Based on Service Classification

Ning Zhang¹*, Bingjun Chen¹, Yansong Yang¹, Huijuan Sun², Ming Chen¹, Tingting Chen¹, Xiaodan Chen¹, Mingming Xiao¹ and Yang Luo³

¹Smart City College, Beijing Union University, Beijing, China
²Institute of Fundamental and Interdisciplinary Sciences, Beijing Union University, Beijing, China
³Institute of Light Wave Technology, Beijing Jiaotong University, Beijing, China

*Corresponding author email: xxzhangning@buu.edu.cn

Abstract. Optical fiber has huge bandwidth, as a physical medium, it has good anti-electromagnetic interference characteristics and excellent security performance, which is very suitable for the establishment of backbone transmission network. Wavelength division multiplexing (WDM) network based on optical fiber has been widely used. Using optical fiber for information transmission can give full play to the nearly unlimited transmission capacity of optical fiber. With the advent of the information age, data service has become the mainstream business, replacing the original telephone voice service. The great development of data transmission service further promotes the continuous development of WDM network technology. Among all kinds of services in optical network, IP service accounts for the largest proportion. In optical networks, switching is an important technology. Network performance is directly related to switching technology. With the development of optical communication technology, a variety of optical switching devices are introduced into WDM optical network, such as optical packet switching, optical burst switching and so on. This makes WDM layer have the ability of dynamic path establishment and removal similar to IP layer. In order to improve the performance of the optical network and reduce the blocking rate of the network, in WDM optical network, the services are designed in different levels. For some very important services, the highest priority is given, and the optical path channel with better survivability and higher fault tolerance is selected. For general services, it can be designed as a lower level service, and choose the appropriate optical path channel for transmission. The experimental results show that this hierarchical service design method can make more effective use of network resources, reduce the network blocking rate, and improve the overall performance of the network.

1. Introduction

Wavelength division multiplexing (WDM) is a high-speed and large capacity optical network transmission technology. WDM technology can use multiplexer to couple optical signals of different wavelengths into a single optical fiber at the transmitting end of the transmission system[1]. At the receiving end, the original optical signals of each wavelength can be separated by using a demultiplexer, which breaks through the transmission limit that only one wavelength optical signal can be transmitted in a single optical fiber, which greatly improves the transmission capacity of optical cable lines[2]. WDM optical network is one of the main networking forms of the next generation interconnection backbone network[3]. Compared with the traditional transmission technology, WDM
technology can increase the transmission capacity of a single optical fiber dozens of times, and can make full use of the huge bandwidth resources of optical fiber, and effectively solve the bandwidth problem of communication transmission[4]. The main transmission medium of WDM network is optical fiber. Using WDM system can save a lot of optical fiber resources, reduce the number of repeaters, and save the construction cost. In addition, WDM transmission system is easy to change and has good scalability. In WDM system, multiplexing technology can carry multiple formats of traffic signals at the same time. These signal wavelengths are independent of each other, so WDM can ensure the transparent transmission of service data[5]. The early WDM systems are all point-to-point architecture. Then, people designed different structural forms, and the ring topology system began to appear. One of the main advantages of this kind of ring system is that it has fast recovery speed. The ring system can be divided into unidirectional loop and bidirectional loop according to the transmission direction, and can be divided into single fiber ring, two fiber ring and multi fiber ring according to the number of adjacent nodes. With the development of WDM system, ring system is also changing, and now it has gradually evolved into mesh system. Mesh system has many advantages, such as high utilization of network resources, good expansibility, flexible network configuration, good survivability, and easy to upgrade and maintain. Therefore, more and more importantly, the network structure conforms to the future development trend, and can adapt to the future development requirements of intelligent and dynamic optical network[6]. Therefore, mesh WDM system will become the main networking mode of optical network in the future. WDM technology has many advantages in network resource utilization, network management and service transmission, so it has been widely used in the backbone network at home and abroad. As the core technology of the next generation optical fiber transmission network, the transmission rate of WDM system is increasing, the network topology is more reasonable, the application range is expanding, the network management is more intelligent, and the service transmission mode is more flexible. However, in the face of the explosive growth of communication network services, the existing WDM optical network also highlights some deficiencies in network resource allocation, traffic control and network reliability assurance. How to design the service level of the network and improve the performance of the whole network has become an urgent task.

2. Optical Network Analysis

Optical networks have been developed step by step. From the historical process of optical network development, the first generation optical network is IP over point-to-point WDM network. In such a network architecture, WDM system is used as a point-to-point high bandwidth channel connecting adjacent IP routers. IP routers are directly connected by multiplexing multiple wavelength channels. At this time, SONET is often used to frame and transmit the overhead information required by WDM channel, while the IP packet of the main part of the information is encapsulated in SONET frame, which is the so-called packet over SONET form. The point-to-point WDM network structure is shown in figure 1(a).

In the IP over point-to-point WDM network, the network topology is fixed, rigid and inflexible, and the network configuration is also static. Now, WDM network equipment has been produced in large quantities. Many IP and WDM equipment manufacturers can provide these devices for IP over point-to-point WDM networks. With the continuous development of communication technology, this WDM network architecture is widely used in long-distance core network.

With the development of network technology, it will enter the second generation network, that is, IP over configurable WDM optical network. In this kind of network, WDM channel can cross connect through OXC node in WDM optical network, and route and forward in WDM optical network system, which can improve the utilization of WDM bandwidth resources and IP interface. In this system, the interface of IP router is connected to OXC of WDM optical network, and OXC of each WDM network is interconnected to form a grid state structure by multiplexing optical fiber of multi wavelength channel. In this network architecture, OXC has the ability to reconfigure the channel. Therefore, WDM system can directly add protection switching and recovery functions to the optical layer without the need for SONET middle layer. Many new WDM cross connect products OXC can support the second generation WDM network. The configurable WDM network structure is shown in figure 1(b).
With the continuous progress of network technology, it will enter the third generation network, which is IP over switched WDM network. In this network, IP packets pass through WDM system directly, and WDM packets are exchanged and transmitted. In other words, WDM system directly supports packet by packet switching instead of providing an ingress to egress optical path, which can provide better wavelength channel granularity. At present, the main optical packet switching technologies include optical burst switching (OBS), optical label switching (OLS), etc.

3. Network Model

There are various forms of optical network in structure. It is found that different optical network forms have different functions. In terms of structure model, there are three kinds of optical network structure models. These three structural models are: overlay model, augmented model and peer model. The overlay model is shown in figure 2.

In overlay model, WDM layer is a kind of service, WDM layer and IP layer are a kind of customer relationship. Here, the identity of IP layer is the customer of WDM layer. IP layer forms its own link by using the connection provided by WDM layer. Under this condition, the management / control mechanism of IP layer and WDM layer is not related, that is to say, the relationship between them is a kind of independent relationship, and they coordinate through the interaction interface defined in advance. Generally speaking, the relationship between IP layer and WDM layer is a relationship between client and server. In optical networks, another model is augmented model. The structure of this model is shown in figure 3.
Figure 3. Augmented model.

In augmented model, although IP layer and WDM layer have a unified address allocation scheme, they are not the same. As a whole network, when routing, the two still have certain independence. WDM layer does not manage IP layer, and IP layer does not manage WDM layer. Therefore, the working mode of this model is still independent of each other. In this model, WDM layer and IP layer have their own routing mode. The connection between WDM layer and IP layer needs to transfer control information between the two routing systems. The last model is the peer model, and its structure is shown in Figure 4.

Figure 4. Peer model.

In the peer model, the nodes in WDM layer do not have a dominant position, and the nodes in IP layer do not have a disadvantage position. Nodes in WDM layer will not lead nodes in IP layer, and nodes in IP layer will not lead nodes in WDM layer. In this kind of network structure, both WDM layer nodes and IP layer nodes have equal status in the network, that is to say, in this peer model, all nodes in the network have the same status. IP layer and WDM layer devices are treated the same, whether WDM layer node or IP layer node, using addressing and routing mechanism is the same. In this model, the network will have a unified control platform to manage the optical network.

4. Service Hierarchical Design

In the optical network, there are a variety of services. How these services are transmitted in the network and how they are transmitted are related to the performance of the network. Some services require quality assurance and priority transmission, while others do not have such strict requirements and can be transmitted when there is a free channel. Therefore, in the process of service transmission, in order to improve the service transmission quality of the network and improve the performance of the whole network, it is necessary to divide the service levels and set different levels for different services. In WDM network, two factors need to be considered when setting the service level. On the one hand, it is for the business of network users, such as web page opening time, file download speed, smooth image and sound without distortion. On the other hand, for WDM optical layer, we need to monitor the signal jitter, signal-to-noise ratio and other physical performance parameters. Therefore, these intuitive indicators and measurable parameters must be taken into account in the hierarchical design of business. In order to make WDM layer work better with IP layer, WDM layer must be able to dynamically configure network resources. In addition to the introduction of optical switch in WDM network to provide hardware support for dynamic resource configuration, a careful design of service classification system is also an essential link in the process of hierarchical setting. In WDM network, in order to effectively utilize the bandwidth resources of WDM layer, it is necessary to provide the ability of quickly establishing and removing optical connection in WDM layer, that is to provide a
dynamic resource allocation function. To provide this function, on the one hand, it needs the support of network hardware, on the other hand, it also needs the assistance of network software. In terms of hardware, the rapid development of optical switch technology provides good support for dynamic optical path establishment.

The design of service grading system is as follows: suppose there are N levels of services, that is to say, the services are divided into N levels, and the rank order is from 1 to N, and N is the highest level. The design principle of different levels is that more wavelength channels can be reserved for high-level services, so that high-level services can be transmitted smoothly. When the amount of high-level traffic is relatively large and the number of wavelength channels reserved is not enough, high-level services can also preempt the low-level wavelength channels to ensure the normal transmission of high-level services. Blocking rate is an important parameter to measure network performance. When network resources are relatively insufficient, it will cause network congestion. At this time, the network performance declines. For example, in the packet switching network, if a large number of packets suddenly rush to the same port, and the switch has no time to process it, it will cause packet loss due to insufficient buffer. For the connection request to establish an optical path, it may be that all wavelength channels in the optical fiber segment have been occupied, or although there are idle channels, wavelength conversion is needed to establish virtual wavelength channels. Such wavelength conversion is beyond the capacity of the network, and network congestion will occur. If the network congestion is serious, it may lead to network paralysis. In addition, the length of network transmission (hop number) will also affect the network blocking rate.

In order to reduce the total blocking rate of the whole network, we can use more reasonable routing and service scheduling algorithm to solve the problem. For WDM network, setting different priority of traffic is an effective way to reduce network blocking rate. The network with service priority is simulated, and the results are shown in figure 5.

![Figure 5. The blocking of priority traffic(PT) and ordinary traffic(OT).](image)

It can be seen from figure 5 that when the network load is relatively light, the traffic priority method can greatly improve the blocking rate; when the network load is heavier, the improvement of the traffic priority method on the blocking rate becomes smaller and smaller. This is because when the network load is heavy, the wavelengths on some optical fibers in the network have been exhausted, and the network is insufficient in terms of wavelength resources. Therefore, even if the network has a service priority method, it can not significantly reduce the blocking rate. In other words, in the case of heavy network load, the main factor leading to the increase of blocking rate is no longer the limitation of wavelength continuity conditions, but the shortage of total network bandwidth resources.

5. Conclusion
The service transmission in optical network is studied. In the network service, the service is classified to meet the quality of service requirements of different types of services. In WDM optical network,
with the increase of transmission rate and multiplexing wavelength channel number, in order to better
guarantee the transmission requirements of different services, different services can be classified. In
terms of blocking rate, different services can be distinguished by giving different priorities to different
services. In case of blocking during transmission, the low priority services should be discarded first. In
the WDM layer, different wavelength channel quotas can be allocated for different traffic flows. The
traffic with low blocking rate is required to allocate more available channels, so it is not easy to be
blocked. The experimental results show that in WDM optical network, this traffic classification
method can reduce the blocking rate and improve the overall performance of the network.

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References
[1] Li X, Zhang L, Wei J, Deep neural network based OSNR and availability predictions for
multicast light-trees in optical WDM networks[J]. Optics express, 2020, 28 (7), pp. 10648-
10669.
[2] Alyatama A, Alotaibi E, Alenezi S, A continuous service model for elastic optical network[J].
Optical & Quantum Electronics, 2020, 52(7), pp. 1-19.
[3] Sayed A, Mustafa F, Khalaf A, et al. Apodized chirped fiber Bragg grating for postdispersion
compensation in wavelength division multiplexing optical networks[J]. Journal of
Communication Systems, 2020, 33(14), pp. 1-13.
[4] Turza K, Krehlik P, Sliwczynski L, Stability Limitations of Optical Frequency Transfer in
Telecommunication DWDM Networks[J]. IEEE transactions on ultrasonics, ferroelectrics, and
frequency control, 2020, 67 (5), pp. 1066-1073.
[5] Kotlyar O, Pankratova M, Kamalian-kopae M, et al. Combining nonlinear Fourier transform
and neural network-based processing in optical communications[J]. Optics letters, 2020, 45(13),
pp. 3462-3465.
[6] Xu H, Yang L, Yu X, et al. Blind and low-complexity modulation format identification scheme
using principal component analysis of Stokes parameters for elastic optical networks[J]. Optics
express, 2020, 28(14), pp. 20249-20263.