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光网络中光信噪比受限的光组播路径分配机制

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摘 要：组播业务的迅速增长对现有光网络的光路分配提出了更高的挑战. 针对在大规模的光网络中，由于光组播路径中光信噪比过低导致传输层光链路无法正常工作，并由此带来“假性信令成功”的问题，提出了一种光信噪比受限的光组播路径分配机制. 该机制充分利用光网络节点中光信噪比监测功能，在信令消息中携带光信噪比性能参量，并在光组播路径分配的信令过程中将光信噪比作为光波长分配的重要依据. 通过该机制，控制平面在信令过程中充分考虑光信噪比因素，确保传输层的光组播路径得以顺利建立并正常工作. 仿真结果表明，所提出的基于光信噪比感知的组播光路分配机制能够解决“假性信令成功”的问题，并有效降低光组播路径的阻塞率.

关键词：光通信；光网络；组播；光路分配；光信噪比；控制平面；信令
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OSNR Constrained Multicast Lightpath Provisioning Mechanism in All Optical Network

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Abstract: In large scale optical networks, great challenge are brought by the fast growing of multicast services. Multicast lightpath-tree may fail to work in data plane due to the low OSNR (optical signal to noise ratio) value, even though the signaling procedure is successful in the control plane. That is called “false signaling-success” in control plane. To solve this problem, an OSNR Constrained Multicast Lightpath Provisioning Mechanism (OC-MLPM) was proposed. The OC-MLPM makes advantage of the OSNR monitoring function in each node, and is able to allocate the wavelength by judging the OSNR value carried in signaling message in order to make sure lightpath could be established smoothly in both data plane and control plane for multicast service. Simulation results show that the OC-MLPM is able to solve the “false signaling-success” problem, and to reduce the blocking probability effectively as well.

Key words: Optical communications; Optical network; Multicast; Lightpath provisioning; Optical signal to noise ratio; Control plane; Signaling
OCIS Codes: 060.4510; 060.2330; 060.4250

0 Introduction

As new IP services emerge and develop rapidly, like Internet of things, great efforts have been made by the researchers and carrier to match the demands of those multicast services[1]. In large-scale all optical network, the efficient lightpath provisioning has become a great challenge to wavelength assignment for multicast services, which are undergoing rapid growth[2-4]. In general, both bandwidth availability and wavelength continuity constraint are key issues when providing lightpath for multicast connections. And the resource reservation protocol with traffic engineering (RSVP-TE) is adopted widely to perform signalling in

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control plane of the optical network[5-6].

With the great progress in wavelength resources assignment research，several mechanisms have been developed，which includes the Source-Initiated Reservation (SIR)[7]；Destination-Initiated Reservation (DIR)[7]，First Fit (FF)[7]，Random Fit (RF)[7]，Contention Detection (CD)[8]，Collision-Aware First Fit (CAFF)[9]，and Circular Wavelength-list (CWL)[10] etc. However，current studies only focus on the wavelength availability and collision from the control plane aspect. In fact，the optical signal to noise ratio (OSNR) is also a crucial factor in the lightpath provisioning. One challenge in large-scale optical network controlled by MPLS-TP is that the lightpath-tree may fail to work in data plane，due to the low OSNR accumulated as the optical signal transport along the multicast lightpath-tree. Under this circumstance，the aim of wavelength assignment for multicast connection is not only to optimize the network resource utilization，but also to select a wavelength to avoid collision and to guarantee reliable OSNR of the wavelength，in order to make sure that lightpath can be set up successfully in the data plane. Otherwise，the lightpath can not be established in data plane，though the signaling procedure is successful in control plane，which we called "false signaling-success". In fact，sometimes the "false signaling-success" in control plane would actually occur，even though the signaling procedure is successfully completed in the control plane. Though some related study has been done in Ref. [10]，it only focuses on single end-to-end unicast and the "signalling false-alarm" problem in multicast condition is still there.

To solve this problem，this paper adds the factor of OSNR into consideration on wavelength provision for multicast requests and proposes an OSNR Constrained multicast lightpath provisioning mechanism (OC-MLPM)，aimed to guarantee that multicast lightpath can be established smoothly and avoid the so-called "false signaling-success".

1 Principle of lightpath OSNR calculation for multicast

With the maturation of optical performance monitoring in data plane，it has become possible and convenient for the control plane of all optical network to obtain those optical performance parameters，including the OSNR[12-13]. Because various OSNR monitoring functions are able to be integrated into the transport plane devices currently，it is convenient for the control plane to collect the OSNR information or value. Thus，the OSNR-constrained factor can be introduced into the control plane of optical network，which means the control plane of optical network is able to be aware of OSNR value and to enhance the lightpath-tree provision ability for multicast services.

The principle of lightpath OSNR calculation of multicast is necessary to discuss in this section. For convenience，it is assumed that EDFAs (Erbium-doped fiber amplifiers) are widely used among the network. There are several factors would cause the degradation of the optical signal. Considering the strong typicality of EDFA factors，this article mainly takes the EDFA into consideration as an example and focuses on the "false signaling-success" problem.

With the maturation of optical performance monitoring technologies，the approach used to calculate the OSNR of EDFA has been well established，since EDFAs are used widely in the optical network[10-15]. If the OSNR of an optical signal is infinite at the input of EDFA，the OSNR at the output is given[13]

$$\mathrm{OSNR}_{\mathrm{EDFA}}=\frac{P_{\mathrm{in}}G}{2n_{\mathrm{sp}}hvB_{\mathrm{o}}} \tag{1}$$

where P_{in} is the signal power at the input of the EDFA，G is the gain of the EDFA，n_{sp} is the population inversion parameter，h is Plank's constant，v is the optical frequency，and B_{o} is the optical bandwidth that measures the OSNR.

To calculate the total ONSR value，some necessary definitions are made as follows：$\mathrm{OSNR}_{\mathrm{link}}$，the link OSNR value of all EDFAs and all wavelength convertors which belong to this link；$\mathrm{OSNR}_{\mathrm{EDFA},\mathrm{I}}$，the OSNR value added by EDFA i；$\mathrm{OSNR}_{\mathrm{init}}$，the initial OSNR value of the optical signal at the ingress node；$\mathrm{OSNR}_{\mathrm{link},k}$，the link OSNR of the link k；N，the number of EDFAs comprising the optical link；M，the number of wavelength convertors comprising the optical link；K，the total number of optical links comprising the lightpath-tree；$\mathrm{OSNR}_{\mathrm{total}}$，the total OSNR value of all links which belong to this multicast tree.

On the basis of these definitions above，the link OSNR value can be obtained using Eq. (2) according to Ref. [11]

$$\mathrm{OSNR}_{\mathrm{link}}=\frac{1}{\sum\limits_{i=1}^{N}(1/\mathrm{OSNR}_{\mathrm{EDFA},i})} \tag{2}$$

Finally，the total OSNR value is estimated by using OSNRs values of all links composing a multicast lightpath

$$\mathrm{OSNR}_{\mathrm{total}}=\frac{1}{1/\mathrm{OSNR}_{\mathrm{init}}+\sum\limits_{k=1}^{K}(1/\mathrm{OSNR}_{\mathrm{link},k})} \tag{3}$$

As the optical signal is transported along the multicast lightpath，its OSNR would deteriorate. If the OSNR deteriorate to some degree，the lightpath would not work in data plane，even through both the signaling procedure and the lightpath setup are successfully completed in control plane. Therefore, this situation is called "false signaling-success" of control plane in this article.

2 OSNR constrained multicast lightpath provisioning mechanism

This study mainly focuses on the problem of "false signaling-success" in signaling procedure of the multicast lightpath establishment. Aimed to solve this problem, an OSNR constrained multicast lightpath provisioning mechanism (OC-MLPM) is proposed. The OC-MLPM makes full advantages of the OSNR monitoring technologies of the data plane, and allows Path Message to carry the OSNR information of each node along the path at the forward detection phase of signaling. By judging the eligibility of OSNR value when allocating wavelength for the connection request, the control plane could avoid the potential or possible "false signaling-success". Moreover, this implies that the data plane and the control plane are more tightly combined when allocating wavelength for multicast connection requests.

In the proposed OC-MLPM, the control plane keeps a list of record about OSNR values collected from the data plane. Additionally, a sub-TLV, which records the OSNR values of each node the Path message goes through, is added into the Path message. When the Path message is received by a mediate node, it will first check the wavelength availability. Then this node will sort all eligible wavelengths by ONSR value, which is stored in the record list. If both constraints are satisfied, the wavelength with the best OSNR value will be selected and assigned to the connection request. If the value of OSNR of the available wavelength fails to meet the requirement, the wavelength provision will be failed, even though there are available wavelengths.

As shown in Fig. 1, the procedure of OC-MLPM is depicted as follows:

Step 1: The mediate node receives the Path message from its upstream node, and abstracts the OSNR value from the Path message of all nodes the Path message goes through along the multicast tree.

Step 2: This mediate node will search the available wavelength for the multicast connection request.

Step 3: The OSNR values of all available wavelengths will be checked according to the OSNR constraint; and this mediate node will abandon those wavelengths that fail to meet the requirement by multicast connection on OSNR.

Step 4: If there are eligible wavelengths, sort all eligible wavelengths by their ONSR value; otherwise, go to the Step 9.

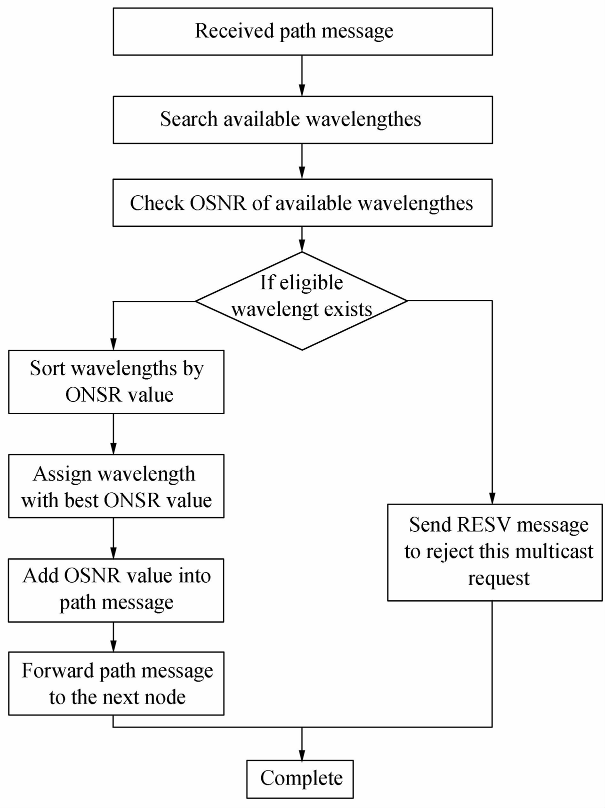

Fig. 1 Mediate node flowchart of OC-MLPM

Step 5: The wavelength with the best OSNR value will be pre-allocated to the connection request.

Step 6: The OSNR value of the pre-allocated wavelength will be added into the Path message, and this Path message will be sent to the next node.

Step 7: A Resv message will be sent from the terminal node to the source node, which will reserve wavelengths resources that satisfies both requirement of availability and OSNR for the multicast connection request.

Step 8: The multicast-tree is really established and the signaling procedure is completed.

Step 9: If there exist no eligible wavelength, Resv messages will be generated and sent to the source node from the destination nodes, and the multicast connection request will be rejected.

3 Simulation results and analysis

In order to evaluate the performance of the proposed mechanisms and demonstrate the validity of the analytical conclusion, a simulation software platform test-bed is constructed. As shown in Fig. 2, the simulated topology consists of 4 interconnected domains each with a 14 nodes 21 links NSFNET (National Science Foundation Network) topology. Assume that there are 16 available wavelengths in each link and the wavelength reservation delay at each node of the segment path is set to be 5 ms. message delivery delay in each link are 1 ms. Connection requests follow the Poisson distribution and are uniformly distributed across the network.

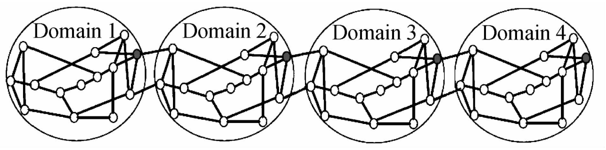

Fig. 2 Network topology

The following five mechanisms are studied in the simulation: FR, FF, OC-MLPM, CD and CWL. The comparison is made by observing 3 major performances: blocking probability without OSNR factor, the real blocking probability with OSNR factor and the average setup time of connections.

In this simulation, OSNR constraint is introduced into consideration. Thus, constraints include the wavelength continuity, wavelength availability and the OSNR eligibility. Moreover, multicast connection requests are set to be Poisson distribution with per minute and their holding-time follow the exponentially distribution with the average value of one minute.

Statistics of blocking probability on both control plane and data plane is conducted. We firstly observe the blocking probability on control plane and show this result in Fig. 3. Then the blocking probability on data plane is obtained and given in Fig. 4. Combining the simulation results of Fig. 3 and Fig. 4, comparison is made on the blocking probability of various schemes.

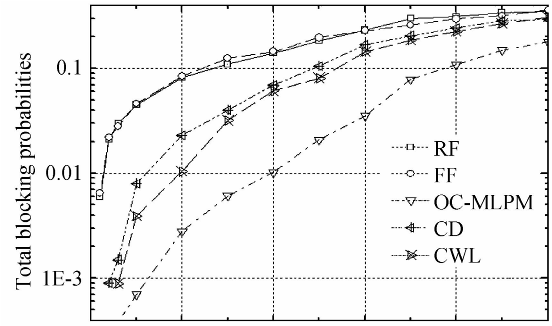

Fig. 3 Blocking probability of control plane

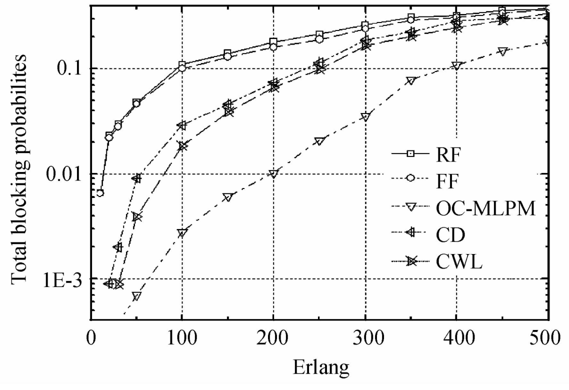

Fig. 4 Blocking probability of data plane

In Fig. 3, the blocking probability from the view of control plane is shown. The OC-MLPM has lower blocking probability than that of others. And CD/CWL schemes are a little worse than the OC-MLPM, while FF/RF show the worst result on blocking probability. The CD failed to solve the more than two connections, while OC-MLPM can solve the same direction collision of more connections by wavelength pre-assignment and schedule, and it can also solve the opposite direction collision. Moreover, CWL is better than FF/RF, but CWL fails to solve collision. Therefore, OC-MLPM performs better than others in blocking probability. Of course, this comparison only considers the wavelength availability and collision from the control plane aspect. What must be pointed out is that, the false successful-signaling exists in all schemes except the OC-MLPM.

The blocking probability from the view of data plane is shown in Fig. 4. By comparing Fig. 4 with Fig. 3, values of all schemes rise in some degree under the OSNR constraint, especially the RF and FF. It is also shown in Fig. 4 that the OC-MLPM can achieve better result than other schemes in the blocking probability from both aspects of data plane and control plane. That is because the "false signaling-success" occurs in other schemes and their total OSNRs may fail to meet requirements by multicast services.

Comparison of the average time of multicast lightpath establishment can be observed in Fig. 5. In this simulation, we take the delay time and process time of signaling message into consideration. As the result shows, values of these five schemes mainly increase slightly as the traffic soars. Values of FF and RF are nearly the same with each other, so is the OC-MLPM. The average setup time of multicast lightpath of CWL is a bit higher than that of the OC-MLPM, because OC-MLPM uses a much easier fixed length array. The average time of connection setup of OC-MLPM/CWL is longer than that of FF/RF/CD. For OC-MLPM/CWL allocates wavelength in the forward phase and backward phase , the increased process

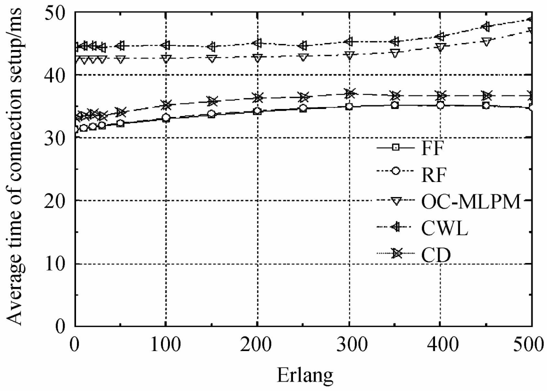

Fig. 5 Comparison of connection setup time

complexity in OC-MLPM/CWL consumes extra time, which is the unavoidable cost of lower blocking probability of the proposed mechanism.

4 Conclusion

In this paper, an OSNR constrained multicast lightpath provisioning mechanism (OC-MLPM) has been proposed, in order to guarantee that the lightpath-tree of multicast can be established smoothly and to avoid "false signalling-success" when establishing lightpath-tree for multicast service in data plane. To evaluate the performance of proposed mechanism, a test-bed of wavelength-routed optical network was designed, and the performances of different assignment schemes have been analyzed. The simulation results reflected better performances of the proposed mechanism in terms of real blocking probability of the light path establishment.

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