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GMPLS 網路架構下的網路流量控衡(1/2)

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Abstract

Generalized multiprotocol label switching (GMPLS) provides a unified control plane that will be an integral part of the next generation data networks. It provides the necessary linkage between the IP and optical layers, allowing interoperable and scalable networks in both the IP and optical domains. In the future all-optical networks consisting of photonic switches, optical cross-connects, routers, DWDM systems, and next generation SONET/SDH equipment, will use the GMPLS control plane to provide services such as dynamic end-to-end connection provisioning, bandwidth-on-demand, automated traffic engineering, and protection/restoration mechanism for a mesh network topology.

Based on the study in first year, we elaborate our knowledge on GMPLS networks to design new network optimization algorithms. In this report, we present our research results on some of the hierarchical cross-connect WDM network related issues, including tunnel allocation, reconfiguration and performance evaluation. Details of the simulation results are not included here for the brevity of this report.

Keywords: DWDM, Generalized Multi-Protocol Label Switching (GMPLS), traffic engineering, hierarchical cross-connect

中文摘要

GMPLS 為下一代資料網路提供了一個整合的控制面，他為 IP 層與光實體層提供了一個聯結，使得 IP 層與光實體層能夠互相溝通。在未來，由光轉換器、光纖路由器、路由器、DWDM 系統、以及下一代 SONET/SDH 設備所構成的全光纖網路，將使用 GMPLS 的控制面來提供諸如動態點對點連結、隨用寬頻、自動流量控衡、網路保護/修復等機制。

基於第一年的研究，我們將我們的知識運用在設計 GMPLS 網路最佳化的演算法。在這份報告中，我們展示我們在多單位光交換器網路相關主題下的研究成果，其中包含了通道建置、通道重置、以及效能的分析。由於篇幅的關係，詳細的模擬結果將不含括在此份報告中。

關鍵詞: DWDM，GMPLS，流量控衡，多單位光交換器

1. Research Objectives

All-optical wavelength-division-multiplexed (WDM) networks are considered to one of the most promising future transport infrastructure to meet the ever-increasing need for bandwidth. Until then, optical cross-connects (OXCs) will inevitably be key components in the networks. However, as the number of wavelength channel increases, the number of ports needed at OXCs also increases, making the size of OXCs too large to implement and maintain. Recently, several types of hierarchical OXC, or multi-granular OXCs (MG-OXCs) have been proposed to handle such scalability problem. The principle is to bundle a group of consecutive wavelength channels together and switch them as a single unit on a specific route so that the number of ports of intermediate cross-connects along the route can be reduced.

In the report, we summarize our research results on some of the MGOXC network issues including:

- Tunnel allocation in hierarchical cross-connect WDM networks.
- Virtual topology reconfiguration in hierarchical cross-connect WDM networks.
- Performance evaluation of multigranularity switching in hierarchical cross-connect WDM networks.

2. Research Methods

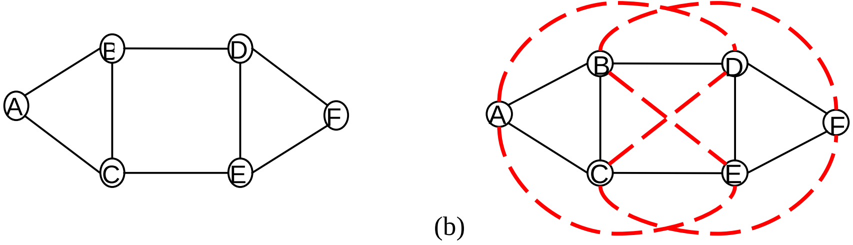
2.1 Tunnel allocation in hierarchical cross-connect WDM networks.

Introduction

In this study, we consider hierarchical wavelength-division-multiplexed (WDM) networks with different switching granularity. Multi-granularity Optical Cross Connect (MG-OXC) [1, 2] is used to bundle wavelengths into a waveband or a fiber tunnel. It is attractive for its scalability and cost reason. However, MG-OXCs complicate the routing and wavelength assignment (RWA) problem. It also increases the blocking probability compared with wavelength switching only network. A heuristic, Capacity-Balanced Static Tunnel Allocation (CB-STA) [1] is proposed to resolve these issues. CB-STA measures the amount of traffic traveling through each node by routing a historical traffic matrix in the network. A node with maximal traffic going in and a node with maximal traffic coming out will be selected to allocate a tunnel between them. In order to utilize the wavelength ports and fibers efficiently, each tunnel established in CB-STA follows a tunnel length constraint which should be equal to an average hop distance. Since CB-STA does not consider the tunnel length constraint while it picks the node pairs, we find that only about 20% of the selected tunnels in CB-STA are complied with length constraint. Therefore, a make-up process is needed in CB-STA to construct the rest of tunnels which may violate the length constraint.

Approach

To overcome this drawback in CB-STA, we propose a heuristic, Weighted Tunnel Allocation (WTA) scheme. Instead of finding ingress and egress node pairs for a tunnel without considering the tunnel length constraint, we only take tunnels which are complied with length constraint into account. Assume all tunnels that obeyed the tunnel length constraint form a set *S*. Our idea is to consider only the tunnels in S. WTA will select an optimal subset of S which can accommodate the most traffic. WTA first modifies a physical network topology by adding all tunnels (i.e. a set of S) which follow the tunnel length constraint into the network. Fig 1 gives a simple example of WTA. Fig 1(a) shows the physical network and in (b), tunnels are added to form an auxiliary graph, where the tunnel length constraint is 2.



(a) (b)

Fig 1. An example of auxiliary graph

Then WTA routes a historical traffic matrix on the auxiliary network using a shortest path algorithm to measure the importance (i.e. weight) of each tunnel. Finally, WTA allocates tunnels according to the non-decreasing order of weight until no more tunnels can be established. Port-Constraint Weighted Tunnel Allocation (PC-WTA) operates in the same way but considering the wavelength port constraint while allocating tunnels. A node that has no enough wavelength switching capability would not be selected as neither ingress nor egress node of a tunnel in PC-WTA. It guarantees that the wavelength switching port can only be used for the tunnels with higher weight.

Simulation Result

The benefits of our approach are demonstrated. Simulation results show that WTA and PC-WTA allocate tunnels efficiently. Comparing with CB-STA, our WTA improve blocking probability by 250% in average under the 1F2B2L MG-OXC configuration (which means each physical link has 1 fiber dedicated for fiber-switching, 2 fibers for waveband-switching and another 2 for lambda-switching). The results also show that when there are few wavelength switching capabilities, considering the lambda switching capability when allocating tunnels can further improve the performance. Simulation results show that PC-WTA further improves about 400% in blocking probability under only one fiber being dedicated for wavelength-switching.

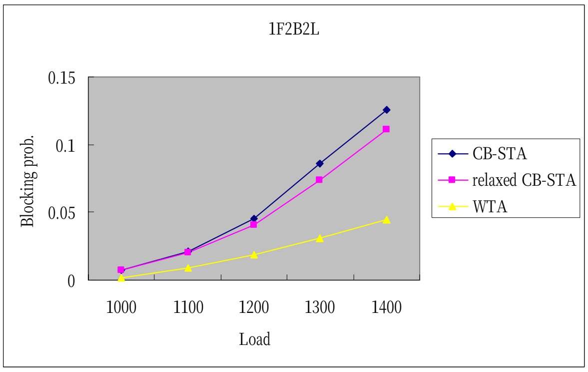


Fig 2. Comparison of blocking probability vs. requests for WTA and CB-STA.

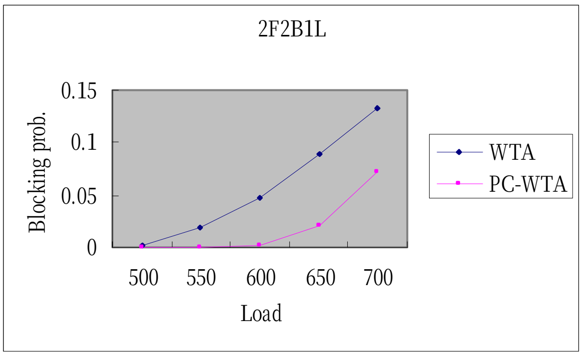


Fig 3. Comparison of blocking probability vs. requests for WTA and PC-WTA.

2.2 Virtual topology reconfiguration in hierarchical cross-connect WDM networks.

Introduction

In hierarchical cross-connect WDM networks, virtual topologies are constructed of lightpaths which may pass through fiber tunnels or waveband tunnels. The virtual topology, for the given traffic demand between node pairs, is designed with objective function such as minimizing maximum congestion [3, 4] on a tunnel. As traffic changes, the original objective function value may not be at the optimal point. For this reason, the set of tunnels needs to be changed for the new traffic. Since the traffic on the tunnels is of the order of gigabits per second, the disruption in traffic needs to be minimized. That is, the number of tunnels added or removed during the reconfiguration process must be as less as possible. If we use objective function to find optimal virtual topology for old and new traffic and migrate from one to the other, the disruption will be large during the reconfiguration process. However, in our approach, we can reduce large number of changes, and achieve almost the same efficiency.

Approach

To minimize the number of changes during reconfiguration process, we prefer to reserve most of the existent tunnels and if not necessary, we prefer to not construct new tunnels. Our approach works as follows. First, we construct an auxiliary network with existent tunnels and all nonexistent tunnels that will possibly be constructed. Second, we give nonexistent tunnels higher cost than the existent ones and route the new traffic on the auxiliary network by using shortest path algorithm to measure the importance (i.e., weight) of each existent or nonexistent tunnel. Finally, we choose the tunnels according to the non-decreasing order of their weights until no more tunnels can be selected to form the new virtual topology. Since the cost of nonexistent tunnels is higher than the existent ones, weights of nonexistent tunnels are usually lower than existent tunnels. Consequently, most existent tunnels will remain in the new virtual topology and only few necessary nonexistent tunnels will be added to the new virtual topology.

Simulation Result

Simulation results demonstrate the benefits of our scheme. The results (Fig. 4 and Fig. 5) show that our reconfiguration process reserves more existent tunnels than optimal solution. Comparing with optimal solution, our scheme has more original existent tunnels under the 2F2B1L MG-OXC architecture [1]. Although the number of modified tunnels is reduced, our scheme still has good performance on blocking rate. There is almost no difference in blocking rates between our scheme and optimal solution.

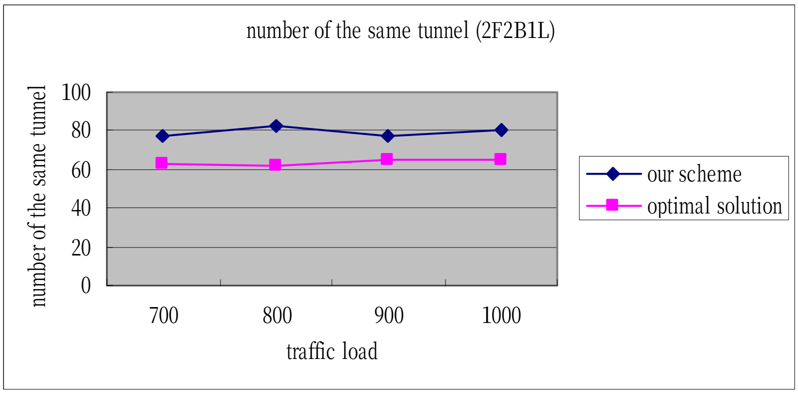


Fig. 4.

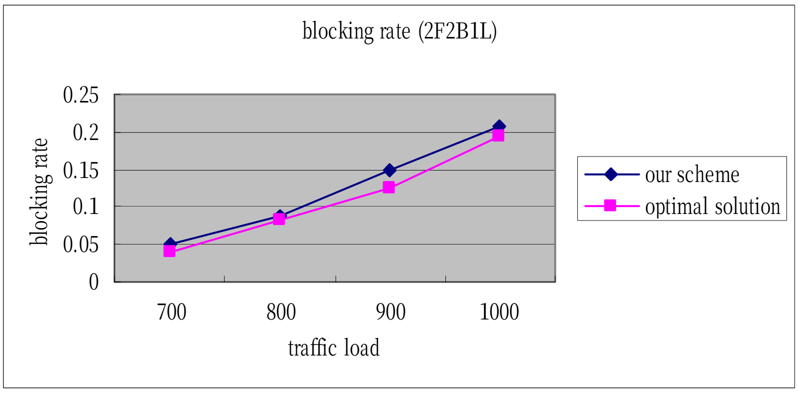


Fig. 5.

2.3 Performance evaluation of multigranularity switching in hierarchical cross-connect WDM networks.

Introduction

Although various MG-OXC architectures and the corresponding heuristics have been proposed, the comparison of performance between them has not yet been extensively studied.

The outcome of the comparison is helpful, for example, for the network service providers to choose the better ones for the future deployment. In this study, we make a simulation-based investigation on two MG-OXC networks with different node architectures, with the object of choosing the better one for future deployment. More specifically, we would choose the one with better performance if both networks cost the same or about the same. Fig.6 and Fig.7 shows the node architectures used in the two networks. In the *homogeneous network*, all the nodes are of the same architecture (Fig. 6) and in the *heterogeneous network*, all the nodes are either of f-node (Fig. 7(a)) or w-node architecture (Fig. 7(b)).

Since many parameters can be tuned to configure a network, there may exist thousands of combinations to configure a network for a fixed amount of cost. To simplify our investigation, we would make some assumptions so that the number of parameters can be greatly reduced and the cost of the network can be easily tuned. We modified the graph model in [5] and develop three heuristics for the two networks to reach for their best performance as possible. Simulation is conducted to support the rationality of our heuristics and to compare the performance of the two networks.

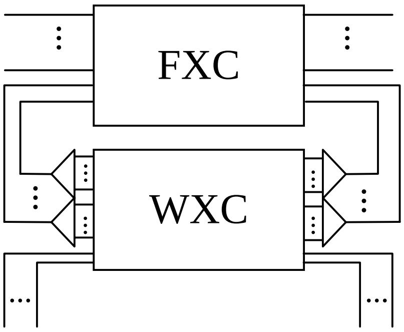


Fig. 6. Node architecture used in homogeneous networks.

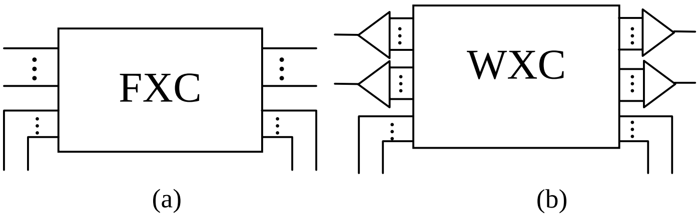


Fig. 7. Node architecture used in heterogeneous networks. (a) fxc-node. (b) wxc-node.

Approach

To satisfy the given lightpath requests, one important observation is that for each lightpath, it is always carried in a specific sequence of tunnels all the way from its sources to its destination. That is, lightpaths are always routed on the virtual topology formed by tunnels. The situation is analogous to the traffic grooming problem in the traditional WDM networks, which is to determine how to set up lightpaths to satisfy the connection requests of the subwavelength granularity. Deriving from the elegant graph model proposed in [5], we make some modifications to the original model to make it applicable in our study. The model basically works as follows. Given the network configuration, including network topology, number of wavelengths in a fiber, number of fibers along a link, number of add/drop ports, etc., an auxiliary graph is first constructed. Then, for each lightpath request, shortest path algorithm is applied to find a path on the auxiliary graph, and if successful, the graph needs to be updated to reflect the remaining resources.

Three heuristics are used in our study. For each network, we need a heuristic to route the given set of lightpath requests, with the object being to minimize the blocking probability. In addition, for the heterogeneous network, before routing the requests, we need a heuristic for the fxc-node assignment when given the number of fxc-nodes to be assigned.

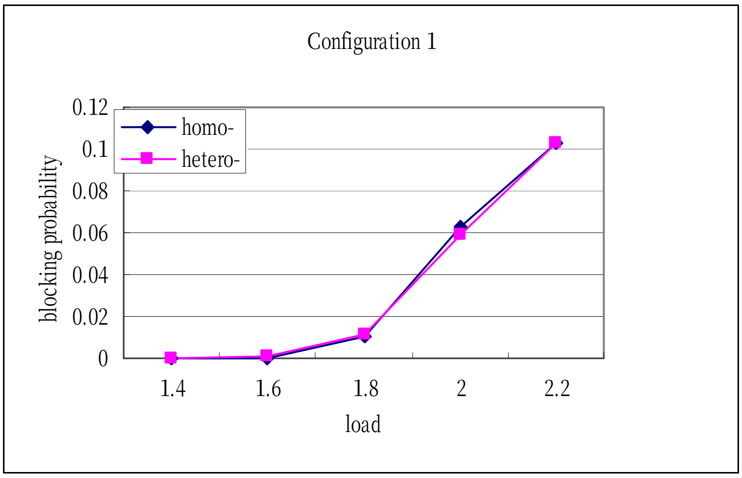
Simulation Result

The simulation is conducted on the randomly generated 24-node regular network topology with degree equal to 3. We assume that each directional link has 4 fibers and each fiber has 16 wavelengths. Table I shows the network configurations we use to compare the performance of the two networks in which α is for homogeneous networks which denotes the ratio of the number of fibers ports connecting to/from the WXC to the number of ports connecting from/to other nodes and ρ is the percentage of fxc-nodes in the heterogeneous network. The network cost is evaluated by the number of mirrors used in the switching fabrics of all the nodes, assuming two-dimensional MEMS technology is used where the number of mirrors taken by a $K \times K$ switch is K^2 [6]. Simulation results are show in Fig. 8. Under configuration 1, performances of the two networks do not have much difference and as the cost drops, it became obvious that the heterogeneous network outperforms the homogeneous network.

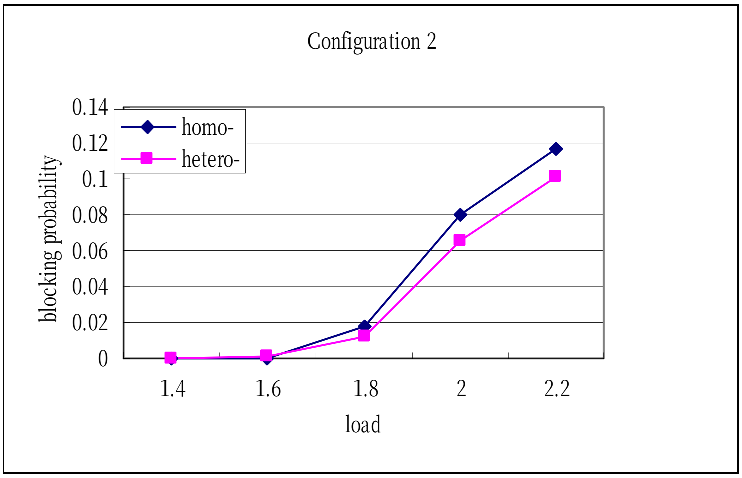
TABLE I

NETWORK CONFIGURATIONS USED TO COMPARE THE PERFORMANCE

	network	α/ρ	# of MEMS
Config. 1.	homo-	75%	2001240
	hetero-	30%	1923264
Config. 2	homo-	67%	1582464
	hetero-	38%	1541184
Config. 3	homo-	59%	1212888
	hetero-	46%	1207744



(a)



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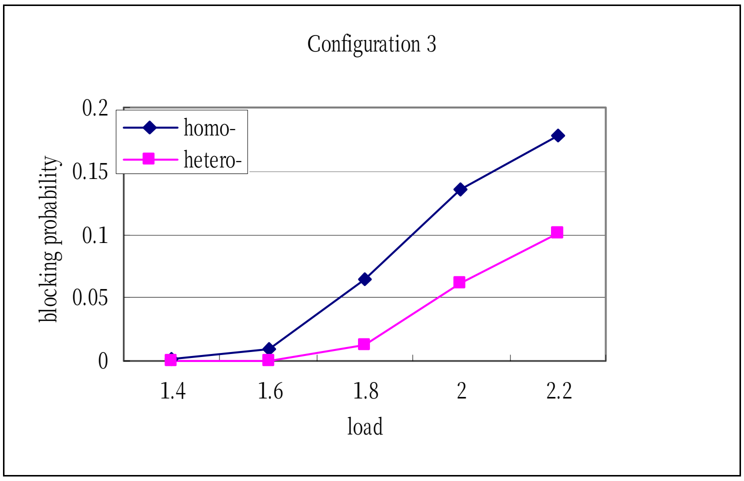

(c)

Fig. 8. Comparison of performances of the two networks under different network configurations.

3. Project Self-Evaluation

In this report, we presented our research results on hierarchical cross-connect WDM networks. Our contributions here include providing efficient solutions to fixed-length tunnel allocation, RWA and reconfiguration problems. Besides, we also compare the performance between different MG-OXC architectures. In the next year, we will work on a simulator to model a GMPLS router. We will simulate the basic functions of each node to investigate the performance of proposed algorithms, including packet routing and GMPLS-based protocols.

4. Reference

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