Wavelength and Port Number Optimization in Distributed Optical Mesh Networks*

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Abstract The dynamic distributed traffic-grooming problem in WDM optical mesh network is investigated. The proposal of the number optimization of wavelengths and ports are given to evaluate in a class of IP/WDM distributed networks. The performances of dynamic distributed traffic grooming presented and compared in regular and irregular optical mesh networks, and give the optimized number of wavelengths and ports in different network condition.

Keywords WDM mesh network; Traffic grooming; The number optimization of wavelengths and ports
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0 Introduction

Wavelength-Division Multiplexing (WDM) is the dominant technology for broadband optical networks for it possible to provision enormous transmission capacity with very low cost, and thus is widely considered as the ideal solution to satisfy the rapid growth in the bandwidth demands in communications networks, which is fueled by the explosion of Internet traffic.

Traffic grooming is the act of efficient multiplexing, demultiplexing, and switching of lower-rate traffic streams (e. g. OC-1, OC-3, OC-12) onto high capacity lightpaths (e. g. OC-48, OC-192, OC-768). Traffic grooming is composed of a rich set of problems, including network planning, static topology design, and dynamic circuit provisioning[1]. Appropriate traffic grooming algorithms enable multiple users to efficiently share the bandwidths of wavelengths, improve the utilization efficiency of network resources, and reduce the network cost. The advantage of traffic grooming is that it achieves better resource utilization through arbitrary bandwidth granularity of the upper (electronical) layers. Although the next generation SDH remains the technology choice of major operators as they migrate towards data-centric networking, as networks evolve to become more IP focused, grooming for IP traffic is becoming an important area for today's work[2].

E. Modiano in [3] considered traffic grooming problem in the IP over WDM networks. If all of traffic on all fibers and on all wavelengths (which amounts to multiple terabits) will have to process at every router, the routers of this size will be very costly. He assumed WDM node could provide optical bypass function. In order to achieve maximum efficiencies, one would need to bundle traffic onto wavelengths so that have to be processed at each router is minimized. Traffic bundling with wavelengths results in reducing the number of add/drop ports needed as well as the total switching capacity at each WDM node. His proposal hints us that we can use effective traffic grooming to achieve the suitable number of wavelengths and ports for each node[3].

Many researchers have studied the problem of wavelengths requirements[4~6]. In this paper, we will give some methods to study the optimal number of wavelengths at each node with different port using strategy in single and multi-fiber distributed controlled IP/WDM mesh networks, then give an upper bund of number of wavelengths in distributed controlled IP/WDM networks.

1 Distributed Signaling Protocol

The other challenge to set up a lightpath dynamically is to develop efficient control schemes in control and management of dynamic traffic grooming in optical networks. Two kinds of control methods, Centralized and Distributed, can be employed in optical networks. In the centralized approach, a central controller maintains a global view of the network about topology information and wavelength usage on each links in the network[7]. Whenever a node requires any information about the topology and routing, it has to consult the controller. But, in large networks, the centralized approach is not feasible because of its huge control overhead. Moreover, if the controller crashes, the whole system cannot work formally.

In distributed-controlled environment, when connections are set up or released very frequently, distributing link state and wavelength usage on each link become impossible because of its huge control

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overhead. Therefore for the distributed schemes, only a part of network view in each node, including network topology, link state and wavelength usage on local links is maintained. Each node will be involved in determining the route and selecting the wavelengths. The connection request goes through each node on the route and reserves wavelengths based on local information at the node either on a hop-by-hop basis or on a parallel basis. Compared with centralized approach, the distributed method spreads computation task to each node along the route. Therefore, it alleviates the bottleneck and improves the reliability of networks. Furthermore, it provides better scalability and interoperability to extend network scale easily.

The distributed scheme has a higher blocking probability than centralized one due to the race conditions among concurrent requests. In the distributed scheme, if several calls arrive in a very close interval, each of them may reserve resources necessary for another, all these calls are blocked because of unavailable resources even if the network has resources for some of them. For simplicity to study, the hop-by-hop and forward reservation approach is employed in our research.

2 Performance Evaluation

We conduct a discrete-event simulator to evaluate the network performance with different wavelength number configured at each node in multi-fiber distributed control optical mesh networks with different port use strategy at each node.

2.1 Experimental setup

The experimental setup for the simulation is based on the following assumptions. The arrival of requests at the network follows a Poisson process with rate λ and is equally likely to be destined to any other node.

1) To achieve the limited wavelengths and ports grooming, the add/drop architecture of a node uses limited number of tunable transmitters and IP/MPLS fabric to finish the function of aggregation different granularities of low-rate traffic to high-rate optical lightpaths. That is, transmitters and receivers at all wavelengths are not employed at each node.

2) The holding time of the requests follows an exponential distribution with unit mean.

3) The switch time, C, the time for configuring the switch matrix at each node, is fixed at 10 ms for each node, which are selected as a typical value.

4) The message processing time in a node, P, is 0.5 ms. Average propagation delay between two nodes D, is proportional to the length of ligthpath delay D = 0.333 ms.

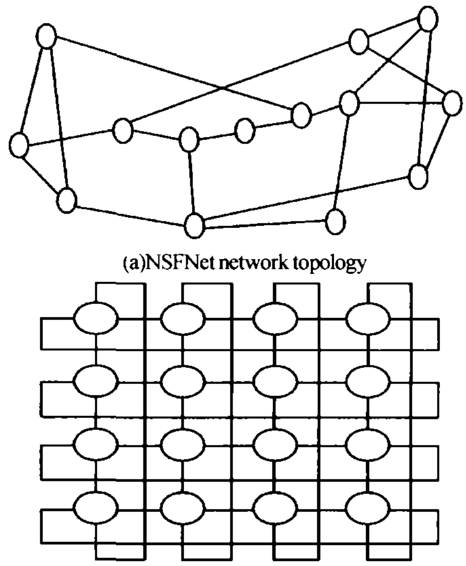
5) FF (First-Fit) is used as default wavelength assignment Algorithm and fixed routing is employed.

6) Two sample networks used in our simulation, an irregularly NSFNet network topology and a regularly 4 x 4 Torus network topology shown in Fig. 1. Total number of nodes in the network N, N = 14 for the NSFNet network, $N = 16$ for the Mesh Torus network.

7) Average hop distance between two nodes H, H = 2.28 for NSFNet network and H = 3.13 for Mesh Torus network.

8) The numbers of fiber F at each link vary from 1 to 4 and each fiber has W wavelengths.

9) The Resource Reservation Protocol (RSVP) uses forward reservation approach.



(a)NSFNet network topology

(b)A 4×4 mesh torus network topology

Fig. 1 The samples of network topology

2.2 Experimental results

In the following figures, each data point is achieved at the condition that 100,000 calls arrive and get through the network. The default traffic load value in our experimental setup is 40 Erlangs. The other experimental environments are described in section 2.1. All simulations are conducted on both irregular NSFNet network and regular Mesh Torus network respectively to compare the network performance for irregular and regular network topology.

2.2.1 Port Number vs. Wavelength Number

Fig. 2 illustrates the relation of wavelength number vs. port number in NSFNet and Torus network. We can find that after wavelength numbers increase to a certain value the port number required varies irregularly within a small number range. We can select the 170 as the maximum number of node ports need at load = 40 Erlangs. So it is a very large number if one port is equipped for each wavelength in a network, and the port utilization is very low. It is not necessary because a lot of resources are wasted and the network costs increases. So without loss of generality, the relationship between the blocking probability and port number can be studied under a typical wavelength number.

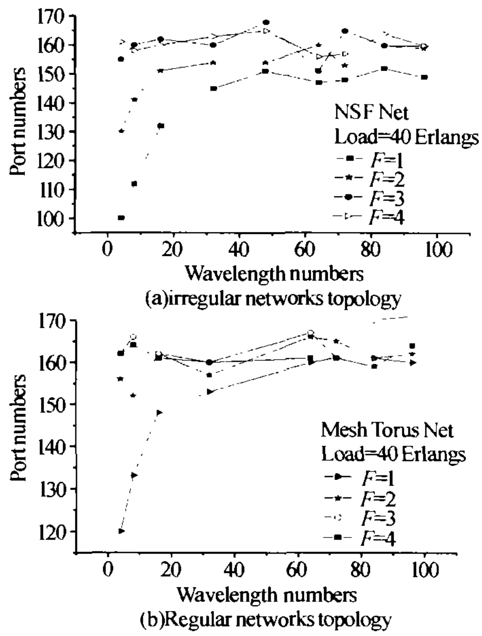


Fig. 2 Regular networks topology

Fig. 3 illustrates the relationship between blocking probability vs. wavelength number and port number at a common traffic load 40 Erlangs in NSFNet and Mesh Torus networks. In Fig. 3, it is shown that the blocking probability decrease with the increase of the port number and the wavelength number. But the blocking probability maintains at a certain value after the wavelength and port number reach certain values. The values are decided by the different network conditions. Fig. 3 also shows the relationship between wavelength number and blocking probability in both Mesh Torus network and NSFNet network with various configurations of fiber number on a link but unlimited node ports. The blocking probability decreases with the increase of the wavelength number in both of the two networks. It is obvious that the wavelength number increase with the fiber number, i. e. the network resource increase. So the contention caused by the absent of network resources could be resolved at a certain extent. But when wavelength number increases to a certain level, the blocking probability nearly keeps a constant value. That means the wavelength numbers also has a suitable value in networks. It means the network traffic load is given, so the need of network resources is approximately definite. Increasing wavelengths and port number can' t improve the performance of network any more. The similar conclusion also can be given at the relationship of blocking probability vs. port number. Therefore we should use a suitable number of wavelengths and ports in a network. The values are decided by the different network conditions.

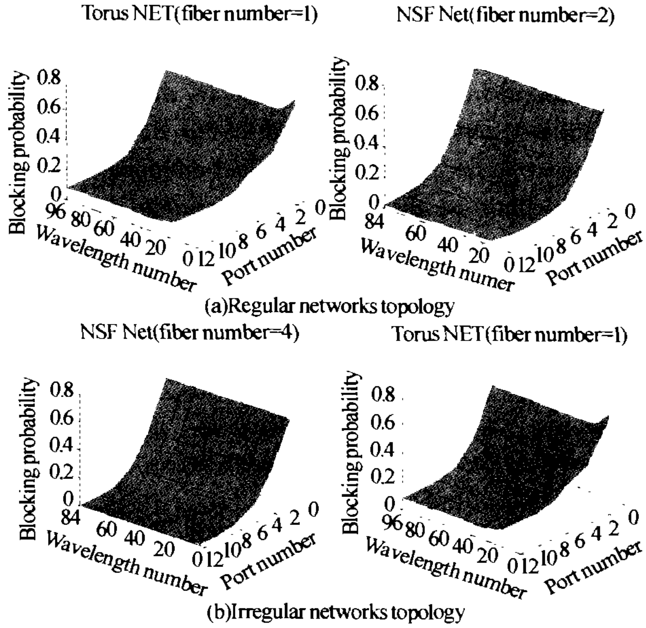


Fig. 3 Blocking probability vs. wavelength number vs. port number

It also shows that the fiber number between nodes has different effects on the blocking probability of network. The more fiber number used, the lower blocking probability at the same wavelength number reach. That is because multi-fiber networks equivalently have partial wavelength conversion capability[8]. An n-fiber m-wavelength network (i. e., there are fibers in each link and wavelengths on each fiber) is functionally equivalent to an nm-wavelength single-fiber network with limited wavelength conversion of degree[8-10].

2. 2. 2 Influence of irregular and regular network topologies

In this study we use a regular networks topology (TorusNet) and irregular networks topology (NSFNet) as the sample networks to simulate our proposal. Fig. 2,3 give the results of irregular and regular network topologies at the same time. We can see that the experimental results of two network topologies are similar at the same conditions. The performance of regular network is a little better because it has less links between two or more nodes.

3 Conclusion

The work was devoted to the traffic-grooming problem in a distributed-controlled WDM mesh network. We have studied the necessary wavelength number needed and the relationship between the wavelength number and port number in distributed environment with Poisson distribution traffic in WDM mesh optical network. The simulation shown that wavelength number and port number can get a suitable value that less than the value of equipped a port for each wavelength to meet the demands of traffic requirements in optical network. We gave the maximum number of port number in the distributed network environments. The result of our study could be a reference to the network design and optimization. But in other condition the same results can be achieved. The optimization of port number and wavelength number at each node is a very complex problem. It still needs further research.

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分布式光网络中的波长和端口数目优化分析

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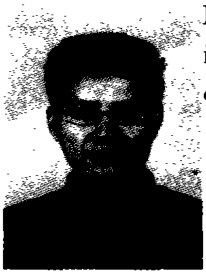
摘 要 研究了分布式 Mesh 光网络中动态业务疏导问题中的波长和端口优化问题,通过对分布式 Mesh 光网络中不同业务和网络拓扑情况下的网络结点波长和端口使用数目的仿真分析,得出网络中的合理波长和端口数目配置,为网络规划和设计提供依据.

关键词 WDM mesh 光网络;业务疏导;波长和端口数优化



Huang Jun was born in 1971. He is pursuing the Ph. D. degree at Shanghai Jiaotong University in optical networks now. His research interests include IP/WDM integration, optical wavelength conversion, optical label switching and optical burst switching.