行政院國家科學委員會專題研究計畫　成果報告

IP over WDM 網路中具服務品質保證及群播技術之研究

(2/2)

計畫類別：個別型計畫
計畫編號：NSC93-2213-E-002-032-
執行期間：93 年 08 月 01 日至 94 年 07 月 31 日
執行單位：國立臺灣大學電機工程學系暨研究所

計畫主持人：廖婉君

報告類型：完整報告

處理方式：本計畫可公開查詢

中　華　民　國 94 年 6 月 14 日

行政院國家科學委員會補助專題研究計畫成果報告

※※※※※※※※※※※※※※※※※※※※※※※※※

IP over WDM 網路中具服務品質保證及群播技術之研究(1/2)

※※※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：■個別型計畫　□整合型計畫
計畫編號：
執行期間：92 年 8 月 1 日至 93 年 7 月 31 日

計畫主持人：廖婉君博士 國立台灣大學電機工程學系
共同主持人：

本成果報告包括以下應繳交之附件：

□赴國外出差或研習心得報告一份
□赴大陸地區出差或研習心得報告一份
□出席國際學術會議心得報告及發表之論文各一份
□國際合作研究計畫國外研究報告書一份

執行單位：國立台灣大學電機工程學系

中華民國九十四年六月三十一日

行政院國家科學委員會專題研究計劃成果報告
IP over WDM 網路中具服務品質保證及群播技術之研究(2/2)

計劃編號：NSC 93－2213－E－002－032
執行期限：93 年 8 月 1 日至 94 年 7 月 31 日

主持人：廖婉君博士 國立台灣大學電機工程學系
計畫參與人員： 劉得煌、郭嘉駿、郭文興、吳岳庭
國立台灣大學電機工程學系

一、 摘要

本年度計畫主要研究分波長多工全光網路(WDM all-optical networks)中品質保證演算法的設計。我們所針對的環境是 OBS 為基礎之全光網路，目前相關研究成果如 JET 機制大都只能在網路不壅塞的環境下運作，一旦網路壅塞，這類作法將退化成無程級的機制。在本年計畫中我們提出演算法改進此缺點，藉由模擬驗證，我們所提出的演算法有較低的阻斷機率及較好的資源使用率。此外，我們亦分析所提出的演算法在壞情況下之效能。

關鍵詞：分波長多工光纖網路、全光網路，群播

Abstract

This project proposes a preemptive multiclass wavelength reservation protocol to provide differentiated service for Optical Burst Switched (OBS) networks, without requiring buffers at the WDM layer. Unlike existing approaches, such as JET QoS, which suffer from implementation constraints and which may degrade to classless schemes, our mechanism is robust and supports an incremental deployment of QoS support and cooperates well with other “best-effort” reservation mechanisms like Horizon and the original JET. We maintain a usage profile for each class at the router, and implement a preemptive wavelength reservation algorithm to ensure QoS. We also conduct simulations to evaluate performance. The result shows that our approach performs best in terms of lower blocking probability and higher resource utilization, making our approach an excellent QoS mechanism for OBS networks.

Keywords：Optical Burst Switching (OBS), WDM, differentiated service, wavelength reservation

二、研究動機與目的

Optical Burst Switching (OBS) [1,2] is a promising solution to provide terabit optical routing and to build an all-optical WDM layer for optical Internet. Based on the concept of “burst” switching, OBS groups several IP packets with the same network egress address and common attributes like quality of services (QoS) into a burst and forwards the burst through the network as a single entity. A burst consists of a burst header and a burst payload. OBS uses physically separate wavelengths/channels to transmit data bursts (i.e., payloads) and their headers, with the burst header being transmitted slightly ahead in time. This allows optical core routers to process the headers electronically, to set up an end-to-end optical path, and to switch data bursts optically. OBS is based on a one-way reservation protocol, in which a data burst follows its header without waiting for an acknowledgment to come back before the data transmission starts.

Current IP technology provides only best effort service to deliver variable length packets. The future Internet may demand differentiated services for multimedia applications. Thus, for the optical Internet to be truly ubiquitous, one must address, among other important issues, how the WDM layer provides differentiated service support.

There are many mechanisms in the literature [3-5] to implement QoS, mostly using buffers and scheduling. These approaches, however, incur high processing overhead at intermediate nodes for switching and mandate a certain amount of buffers. No efficient optical buffer is available today. The use of electronic buffers necessitates opto-electro-optic (O/E/O) conversions, which must be avoided in an all-optical network where data is kept in the optical domain at all intermediate nodes. This calls for new QoS mechanisms for OBS WDM networks.

[6] proposed a new approach to differentiating services without requiring buffers at the WDM layer (we call it "JET QoS" in the rest of the paper). Taking advantage of the offset time between the burst header and its data burst, JET QoS assigned different "extra" offset times to different classes of traffic. The extra offset time of each higher-class must be larger than the maximum burst length of all lower-class bursts, and each higher class must take a longer reservation delay (i.e., extra offset time) than all the lower classes. As a result, a higher priority class could be isolated from lower priority classes, thus ensuring different blocking probabilities for different classes of traffic. This approach, however, has two constraints when used to provide basic QoS service. First, it requires all the routers to implement the same JET mechanism as in [7]. Second, all edge routers must use the same burst length and offset time for the same class of traffic. These two constraints limit the practical use of the JET QoS mechanism. In addition to these constraints, JET QoS service may degrade to classless (i.e., best effort) service, explained as follows. The extra offset time is assigned at the edge router, and must be strictly enforced at all intermediate core routers. However, such offset times may not maintainable at the core routers due to longer rerouting paths, congestion in the control channel, and different offsets and burst durations in a big OBS network operating on different network technologies by different organizations. The JET QoS mechanism fails under these circumstances.

This paper proposes a preemptive wavelength reservation protocol to provide differentiated service for OBS networks without requiring buffers at the WDM layer. Unlike JET QoS which has many implementation constraints and may degrade to a classless mechanism, our protocol supports an incremental deployment of QoS support and cooperates well with other "best-effort" reservation mechanisms like Horizon [1] and the original JET [7]. We maintain a usage profile for each class at the router, and implement a preemptive wavelength reservation algorithm to ensure QoS. Simulations were conducted to evaluate performance. The result shows that our approach performs best in terms of lower blocking probability and higher resource utilization, making our approach an excellent QoS mechanism for OBS networks.

The rest of the paper is organized as follows. Section 2 describes the proposed preemptive multiclass wavelength reservation protocol. Section 3 presents the simulation study to evaluate the performance of the proposed mechanism. Finally the concluding remarks are included in Section 4.

三、多乘級光波長保留演算法

This section describes the proposed preemptive multiclass wavelength reservation mechanism for the OBS network.

(a) Protocol Fundamentals

Suppose that a switch has a total of m wavelengths per output link to serve data bursts. Considering the characteristics of traffic, we classify bursts into k different classes, say $c_1, c_2, \Lambda\ c_k$. To differentiate service to different classes of bursts, each class is assigned a service priority. Without loss of generality, the priority of classes $c_1, c_2, \Lambda\ c_k$ is assumed to be in an ascending order of $c_1 < c_2 < \Lambda < c_k$. The higher the priority, the lower the blocking probability. This implies that if class c_j has priority over class c_i, class c_j bursts are allowed to use more resources (i.e., wavelengths) than class c_i bursts. The switch assigns each class a usage limit, defined as a percentage of system utilization (in terms of the number of wavelengths) the class is allowed to use. Let p_i be the usage limit assigned to class c_i requests. $\sum_{i=1}^{k} p_i = 1$, and $p_1 < p_2 < \Lambda < p_k$.

In our protocol, the switch assigns a usage limit to each service class, and maintains a usage profile per class to monitor their current usages. Based on the profile table, the switch can determine if there is an *eligible* wavelength for a new request. A wavelength is eligible for a request, say R, if it is not assigned to any other request during the burst duration of request R. The entry of the usage profile records a predefined usage limit, the current usage, and a list of granted requests with the following triple: burst duration, outgoing wavelength, and a predefined timer. The burst duration can be obtained from the burst header, which carries the offset time to the data burst and the burst length. Let l, s, and e be the burst length, the start time and the end time of the data burst, respectively. The start time, s, is equal to the current time plus the offset time carried in the burst header, and $e = s + l$. The burst duration is maintained with the format of (the start time, the end time) of the data burst. The outgoing wavelength may be an eligible or preempted wavelength scheduled to transmit the data burst. The predefined timer records the maximum tolerable time to wait for the receipt of the data burst, in an attempt to cope with network faults and the preemption allowed by our protocol.

(b) In-Profile Verification

A class of traffic is said to be in profile if its current usage does not exceed a predefined limit; otherwise, the class is out of profile. The following approach can be used to determine if a class is in profile. Assume there are n class c_i

requests granted. Let l_x be the burst length of a class c_i request R_x, $x = 1\Lambda\ n$, and μ_i, the current total usage of class c_i. $\mu_i = \frac{\sum_{x=1}^{n} l_x}{m \times (T - t_0)}$, where t_0 is the current time and T is the last finished time defined as $T = \max_{x=1\Lambda\ n}\{e_x\}$, e_x is the end time of request R_x. Class c_i is said to be in profile if $\mu_i \le p_i$; otherwise, the class is out of profile.

(c) Burst Preemption

Assume that a switch has newly received an in-profile class request, say R_x, with start and end times of s_x and e_x, respectively. Let C_O be a set of out-of-profile classes, defined as

(1) $C_O = \{c_i \mid \mu_i > p_i, i = 1,2,\Lambda\ k\}$

(2) $\forall c_i \in C_O, \exists R_v \in c_i$, $s_x \ge s_v$ and $e_x \le e_v$.

where μ_i and p_i are the current usage and the usage limit of class c_i, respectively; s_v and e_v are the start and end time of request R_v, respectively. These two conditions imply that every class in C_O must be out-of-profile (by condition (1)), and must at least include a request previously granted but its start time being slightly ahead and its data burst overlapping in time with the in-profile request newly received (condition (2)). In other words, the wavelength scheduled to any request of a class in C_O, say R_p, can be used to serve R_x if R_p is preempted.

Suppose that a switch has no eligible wavelength available to serve an in-profile request R_x. The preemption process is triggered and proceeds as follows. The switch preempts a granted wavelength from the class with the lowest priority in C_O, and updates the current usage accordingly. Assume that c_a is the lowest priority class in C_O, and contains a set of requests $\{R_v \mid s_x \ge s_v, e_x \le e_v, v = 1,2,\Lambda\ m\}$. Request R_p in c_a is the victim to be preempted if $l_p \le l_i$ and $e_p \ge e_i$, $i = 1\Lambda\ m$.

(d) Operation Overview

A switch keeps monitoring its usage profile table. Upon receiving a class c_i request, the switch first attempts to identify an eligible wavelength for the request. If the attempt succeeds, the request is granted, and the usage profile of class c_i is updated; otherwise, the following takes place. The switch first examines if the class to which the request belongs is in profile, using the in-profile verification algorithm described in Sec. 2.2. If it is in profile, the switch preempts a previous granted request from an "out-of-profile" class using the burst preemption algorithm described in Sec. 2.3; otherwise, request R is rejected and the data burst is just simply dropped.

A switch may grant a request either with an eligible wavelength, or a preempted wavelength. Once the request is granted, the switch records the information of burst duration and outgoing wavelength for the request in the corresponding usage profile. To prevent a granted request from being preempted by any switch in the data channel, thereby wasting resources in the reserved path, we associate each pair of (burst duration, outgoing wavelength) with a predefined timer. The timer is activated at the requested start time of a burst, and in the middle of any burst transmission when data packet is not received in time as expected. On expiry of the timer, the switch assumes an occurrence of a fault (either a physical fault or a preemption) if no data burst has been received. It then removes the switching information of the associated burst, and makes the wavelength available for other requests.

四、效能分析

This section presents the simulation results to compare the performance of the proposed mechanism with classless (i.e., best effort) and JET QoS [6]. The classless mechanism may be Horizon [1] or the original JET [7]. The following results are obtained with the original JET. The JET QoS is the original JET with different extra offset times assigned to different classes of bursts.

We consider bufferless switches with *m* wavelengths in each output link. Each switch is assumed to be capable of full wavelength conversion. We assume there are *k* classes, all of which generate bursts with an exponential inter-arrival time and exponential burst duration. To simplify the computation and without loss of generality, the simulation is based on the assumption that all sources have the same arrival rates (i.e., $\lambda_1 = \lambda_2 = \Lambda = \lambda_k = \lambda$) and service rates (i.e., $\mu_1 = \mu_2 = \Lambda = \mu_k = \mu$).

(a) Blocking Probability

This experiment investigates the blocking probability of different mechanisms as a function of the offered load in a single bufferless WDM switch. The offered load here is defined as $\frac{\sum_i \lambda_i}{m\mu}$, where *m* is the number of wavelengths in each link, λ_i is the arrival rate of class c_i and μ is the service rate of each burst. We first consider two classes only, namely, classes 1 and 2, in an attempt to observe the service differentiation offered by each mechanism. We let class 2 have priority over class 1, and assign the usage limits of 0.0 and 1.0 to classes 1 and 2, respectively. Thus, class 2's traffic can preempt class 1's traffic when necessary.

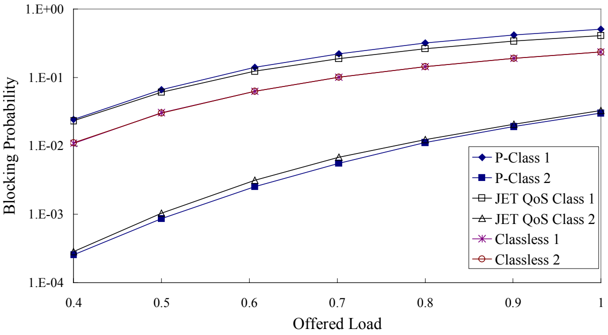

Figure 1. Blocking probabilities of the three mechanisms

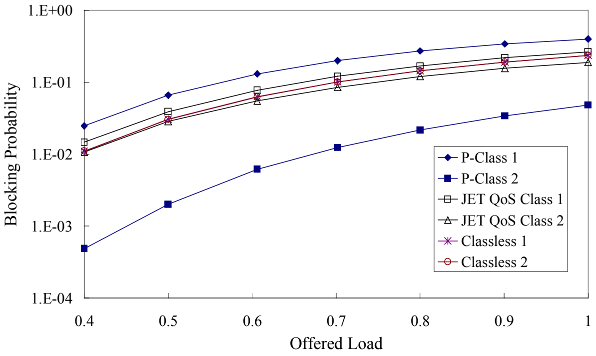

Figure 2. Blocking probabilities of the three mechanisms with network congestion

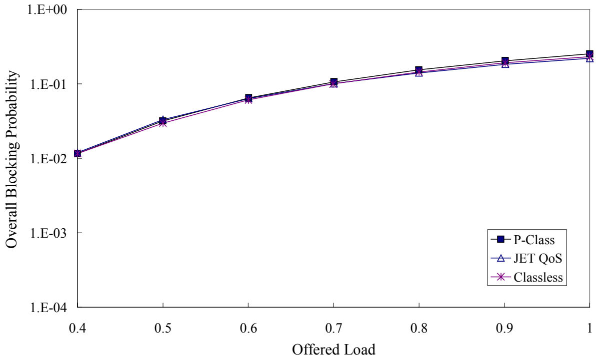

Figure 3. Overall blocking probabilities of the three mechanisms

Fig. 1 shows that the blocking probabilities of the three approaches when each output link has 8 wavelengths. These blocking probability curves increase as the offered load increases.

Both JET QoS and the proposed preemptive approach (denoted P in the figure) provide service differentiation for multiclass traffic. While the difference is small, the blocking probability of class-2 traffic in our approach is always lower than that in JET QoS. Fig. 2 shows the blocking probabilities of the three approaches when the offset delay time becomes invalid due to network congestion. It can be observed that our approach still provides differentiated service for classes 1 and 2 traffic, while JET QoS degrades into a classless scheme. Fig. 3 shows the overall blocking probabilities of the three mechanisms. It can be seen that the three curves overlapped, obeying the conservation law of the system.

We then extend k from two to four classes with the following priority: class 4 > class 3 > class 2 > class 1. Fig. 4 shows the class blocking probabilities of classes 1 to 4, with the usage limits of 0.75, 0.2, 0.05, and 0.0 for the four classes, respectively. The higher the offered load is, the higher the blocking probability. Note that the blocking probability is closely related to the usage limit. Either can be derived with a priority queuing system with preemption when the other is given. Thus, the service provider can assign a usage limit to a class once the guaranteed blocking probability for the class is determined.

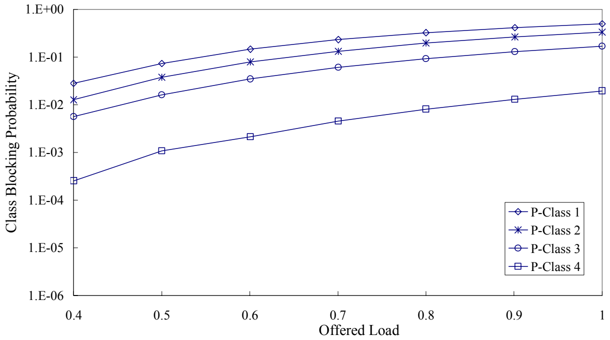

Figure 4. Class blocking probabilities of four classes

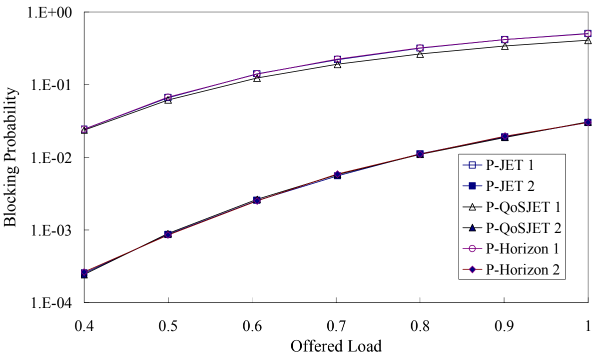

Figure 5. Blocking probabilities of three reservation mechanisms in cooperation with our protocol

Fig. 5 shows the blocking probability of the proposed mechanism in cooperation with two "best effort" mechanisms, Horizon and the original JET, and with JET QoS. It shows that our approach can work well with existing reservation mechanisms and provide/improve their provision of service differentiation for different classes of traffic.

(b) Resource Utilization

The second experiment studies the resource utilization of each mechanism with four classes of traffic in the network shown in Fig. 6. The utilization is defined as $U = \frac{\sum_i \lambda_i \times (1-\Pr(i))}{m\mu}$, where λ_i is the arrival rate of class c_i burst, $\Pr(i)$ is the blocking probability of class c_i, and μ is the service rate of each burst. In the simulation, the extra offset time of JET QoS is defined as $3L \times Q_i$, where L is the burst length, and Q_i, the number of traffic classes. In our protocol, we use the same setting as Fig. 1, i.e., the usage limits of classes 1 and 2 are 0 and 1, respectively.

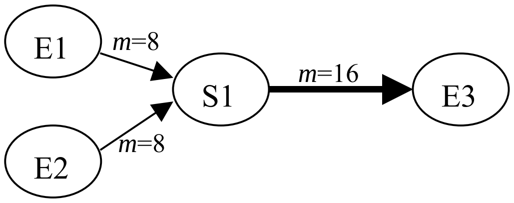

Figure 6. Network topology of the utilization experiment

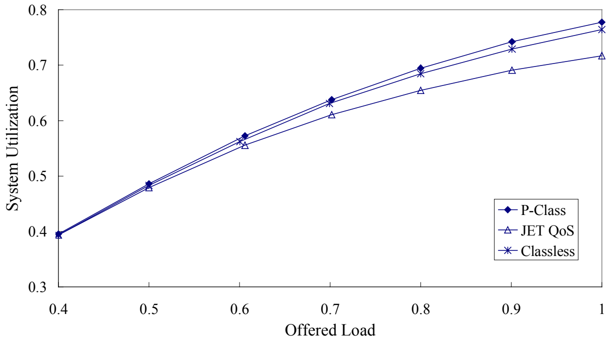

Figure 7. Resource utilization of the three mechanisms

Fig. 7 shows the utilization curves of the three approaches as a function of offered load. The overall utilization increases as the offered load increases. While the three curves are close, the proposed preemptive mechanism has the best utilization, followed by the classless mechanism, and then JET QoS. The high utilization of the proposed mechanism is mainly due to the preemptive wavelength reservation mechanism with reservation clearance using a soft state timer.

五、結論

In this project, we have described a new bufferless mechanism using a preemptive wavelength reservation mechanism to differentiate services in optical burst switched WDM networks. Unlike JET QoS has many implementation constraints and which may degrade to a classless scheme, our mechanism is robust and supports an incremental deployment of QoS support and cooperates well with other "best-effort" reservation mechanisms like Horizon and the original JET, and even with JET QoS. We maintain a usage profile for each class at the router, and implement a preemptive wavelength reservation algorithm to ensure QoS. We have also conducted simulations to evaluate performance. The result shows that our approach performs best in terms of lower blocking probability and higher resource utilization, making our approach an excellent QoS mechanism for OBS networks.

參考資料

[1] Y. Xiong, M. Vandenhoute, and H. C. Cankaya, "Control Architecture in Optical Burst-Switched WDM Networks," *IEEE JSAC*, vol. 18, no. 10, pp. 1838-1851, Oct. 2000.

[2] C. Qiao and M. Yoo, " Optical Burst Switching (OBS) – A New Paradigm for an Optical Internet," *Journal of High Speed Network*, vol. 8, no. 1, pp. 69-84, 1999.

[3] H. Zhang, "Service Disciplines for Guaranteed Performance service in Packet Switching Networks," *Proc. of the IEEE*, vol. 83, pp. 1374-1396, Oct. 1995.

[4] A. Varma and D. Stilladis, "Hardware Implementation of Fair Queuing Algorithms for Asynchronous Transfer Mode Networks," *IEEE Communications Magazine*, vol. 35, pp. 74-80, Dec. 1997.

[5] U. Briem et al., "The Traffic Management for an ATM Switch with per-VC Queuing: Concept and Implementation," *IEEE Communications Magazine*, vol. 36, pp. 88-93, Jan. 1998.

[6] M. Yoo and C. Qiao, "Supporting Multiple Classes of Services in IP over WDM Networks," *Proc. IEEE Globecom '99*, pp. 1023-1027.

[7] M. Yoo and C. Qiao, "Just-Enough-Time(JET): A High Speed Protocol for Bursty Traffic in Optical Networks," *Dig. of IEEE/LEOS Summer Topical Mtgs. Technologies for a Global Info. Infrastructure*, pp. 26-27. Aug. 1997.