行政院國家科學委員會專題研究計畫　期中進度報告

總計畫(1/3)

計畫類別：整合型計畫
計畫編號：NSC92-2213-E-009-115-
執行期間：92 年 08 月 01 日至 93 年 07 月 31 日
執行單位：國立交通大學資訊工程學系

計畫主持人：楊啟瑞
共同主持人：張仲儒，陳伯寧，陳耀宗

報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國 93 年 6 月 10 日

行政院國家科學委員會專題研究計畫成果報告

支援下一代無線與 FTTx 擷取之光纖都會網路技術

Optical Metro Core Network Transport Supporting Next Generation Wireless and FTTx Access Technology

計畫編號：NSC92-2213-E-009-115

執行期限： 92 **年** 8 **月** 1 **日至** 93 **年** 7 **月** 31 **日**

主持人：楊啟瑞　　國立交通大學資訊工程研究所

共同主持人：張仲儒教授、陳伯寧教授（交大電信工程學系）

陳耀宗教授（交大資訊工程學系）

一、中文摘要

網際網路頻寬需求成長，及光纖波分多工(WDM)**與無線通訊領域上之快速進展, 導致下一世代網路的設計與實現有巨大的改變。目前最有潛力的下一世代網路技術即為光纖擷取網路及無線擷取網路。**

本整合型研究計畫旨在探討以光纖都會核心為主幹，支援無線擷取網路與光纖擷取網路之基本傳輸及服務品質保證(QoS)**技術。此計畫分為四項子計畫：子計畫一探討以**packet-over-WDM (PoW)**光纖架構為主的都會型核心網路骨幹技術，包含軟硬體研究平台之建構及訊務工程控制與分析；子計畫二主要探討基本無線傳輸之編碼與解碼技術，包含將通道參數估量和通道效應等化結合至通道編碼設計，以及如何於在以符元**(symbol)**為傳送單位的高速率傳輸調變下進行位元**(bit)**為解碼單位的軟性解碼**(soft-decoding)**；子計畫三負責探討以光纖架構為主之擷取網路，包含建立於全光巨量交換系統**(OBS)**之品質保證服務**(QoS)**機制，訊務彙集**(traffic grooming)**以及乙太光纖被動網路**(EPON)**之研究；子計畫四則負責研究快速行動性**(High mobility)**下無線網際網路之品質服務**(QoS)**技術，以能夠平順地支援無接縫式的即時多媒體串流**(Real-time Multimedia Streaming)**為目標。**

關鍵詞：波分多工(WDM)**，長途主幹網路，都會型網路**(MAN)**，波分多工封包**(PoW)**，光電路交換**(OCS)**，全光巨量交換系統**(OBS)**，服務品質保證**(QoS)**，媒體擷取控制**(MAC)**，無線擷取網路，訊務彙集，乙太光纖被動網路**(EPON)**，錯誤更正碼，編碼與解碼技術。**

二、英文摘要

The ever-growing demand for Internet bandwidth and recent advances in optical Wavelength Division Multiplexing (WDM) and wireless technologies brings about fundamental changes in the design and implementation of the next generation networks. The next challenge in wireless communications would be to reach high transmission rate under high mobility.

The main objective of this integrated project is the provision of the basic transport and QoS guarantees over metropolitan optical and wireless access networks interconnected via optical metro core backbone networks. There are 4 subprojects in the integrated project. Subproject 1 is responsible for the design, analyses, and testbed construction of packet-directly-over-WDM metro core networks; Subproject 2 focuses on the systematical design of an error-correcting code that can at the same time equalizes channel effect, and bit-wise soft-decision decoding for the prevailing symbol-based modulation scheme for future high speed transmission; Subproject 3 aims at the design and analyses of optical access networks including OBS-based optical transport with QoS guarantees, traffic grooming, and Ethernet over Passive Optical Network (EPON) and finally Subproject 4 then investigates QoS enabling technology under a high mobility wireless environment, in an attempt to smoothly support the seamless real-time multimedia streaming.

Keywords: Wavelength Division Multiplexing (WDM), Long-haul backbone network, Metropolitan Area Network (MAN), packet-over-WDM (PoW), Optical Circuit Switching (OCS), Quality-of-Service (QoS), Medium Access Control (MAC), Wireless Access Networks, Traffic Grooming, Ethernet over Passive Optical Network (EPON), Error Correcting Coding, Encoding and Decoding.

三、計畫緣由與目的

The ever-growing demand for Internet bandwidth and recent advances in optical Wavelength Division Multiplexing (WDM) and wireless technologies brings about fundamental changes in the design and implementation of the next generation networks. To support end-to-end data transport, there are three types of networks: wide-area long-haul backbone network, metropolitan core network, and local and access networks. First, due to steady traffic resulting from high degree of multiplexing, next-generation long-haul networks are based on the Optical Circuit Switching (OCS) technology by simply making relatively static WDM channel utilization. Second, a metropolitan core network behaves as transitional bandwidth distributors between the optical Internet and access networks. Unlike long-haul backbone networks, metro networks exhibit highly dynamic traffic demand, rendering static WDM channel utilization completely infeasible. Finally, access networks are responsible for providing bandwidth directly to end-users. Two most promising technologies have been optical access and wireless access networks, respectively. Due to superior performance of fiber optics and tremendous bandwidth demand, providing broadband access and services through optical access technology becomes indispensable. Finally, regarding wireless access networks, the new demand of wireless communications in recent years inspires a quick advance in wireless transmission technology. Technology blossoms in both high-mobility low-bit-rate and low-mobility high-bit-rate transmissions. Apparently, the next challenge in wireless communications would be to reach high transmission rate under high mobility.

The main objective of this integrated project is the provision of the basic transport and QoS guarantees over metropolitan optical and wireless access networks interconnected via optical metro core backbone networks. As shown in Figure 1, Subproject 1 (PI: Prof. Maria Yuang) is responsible for the design, analyses, and testbed construction of packet-directly-over-WDM metro core networks; Subproject 2 (PI: Po-Ning Chen) focuses on the systematical design of an error- correcting code that can at the same time equalizes channel effect, and bit-wise soft-decision decoding for the prevailing symbol-based modulation scheme for future high speed transmission; Subproject 3 (PI: Prof. Chung-Ju Chang) aims at the design and analyses of optical access networks including OBS-based optical transport with QoS guarantees, traffic grooming, and Ethernet over Passive Optical Network (EPON) and finally Subproject 4 (PI: Prof. Y. C. Chen) then investigates QoS enabling technology under a high mobility wireless environment, in an attempt to smoothly support the seamless real-time multimedia streaming.

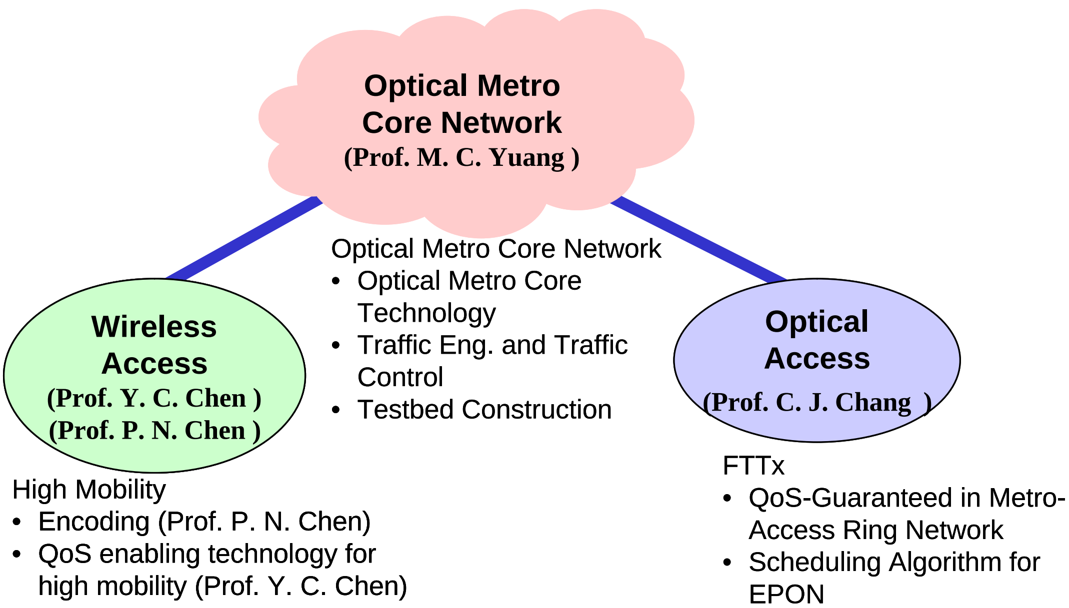


Figure 1. Relationship between sub-projects.

四、成果與討論

● 子計畫一：光纖都會核心網路技術研究

In this subproject, we have proposed a new Optical Coarse Packet Switching (OCPS) [1] paradigm for OCPS mesh-based metro core networks. Combining the best of OPS [2-4] and OBS [5-10], OCPS advocates the enforcement of manageable traffic control and engineering to realize bandwidth-on-demand on sub-wavelength basis while circumventing OPS limitations. Based on OCPS, we have constructed an experimental optical IP-over-WDM network testbed, referred to as OPSINET, as shown in Figure 2. OPSINET consists of three types of nodes-edge routers, optical lambda/fiber switches (OXCs), and Optical Label Switched Routers (OLSRs). To facilitate traffic engineering, OPSINET is augmented with an out-of-band Generalized Multiprotocol Label Switching (GMPLS) [11] control network. In sequel, we focus on QoS burstification control of OPSINET.

The QoS burstification control of OPSINET is performed by a QoS-enhanced traffic control scheme, called (y,t)-Scheduler/Shaper, where y and t are the maximum burst size (packet count) and maximum burst assembly time, respectively. Essentially, (y,t)-Scheduler/Shaper is a dual-purpose scheme. It is a scheduler for packets, abbreviated as **(y,t)-Scheduler**, which performs the scheduling of different delay class packets into back-to-back bursts. On the other hand, it is a shaper for bursts, referred to as **(y,t)-Shaper**, which determines the sizes and departure times of bursts.

To provide delay class differentiation, for IP packet flows designated with delay-associated weights, (y,t)-Scheduler performs packet scheduling and assembly into bursts based on their weights and a *virtual window* of size y. The Scheduler exerts simple FIFO service within the window and assures weight-proportional service at the window boundary. The scheme, as will be shown, provides different classes of 99% delay bound guarantees.

To provide loss class differentiation, (y,t)-Shaper facilitates traffic shaping with a larger burst size (y) assigned to a higher priority class. To examine the shaping effect on loss performance, we analytically derive the departure process of (y,t)-Shaper. The aggregate packet arrivals are modeled as a two-state Markov Modulated Bernoulli Process (MMBP) with batch arrivals. Analytical results delineate that (y,t)-Shaper yields substantial reduction in the Coefficient of Variation (CoV) of the burst inter-departure time. The greater the burst size, the more reduction in the CoV.

Furthermore, we conduct network-wide simulations to draw loss performance comparisons between OCPS and JET-based OBS [6]. Simulation results demonstrated that, due to the near-far problem [12], OBS undergoes several orders of magnitude increase in packet loss probability for Class H traffic particularly under a smaller burst size. As opposed to

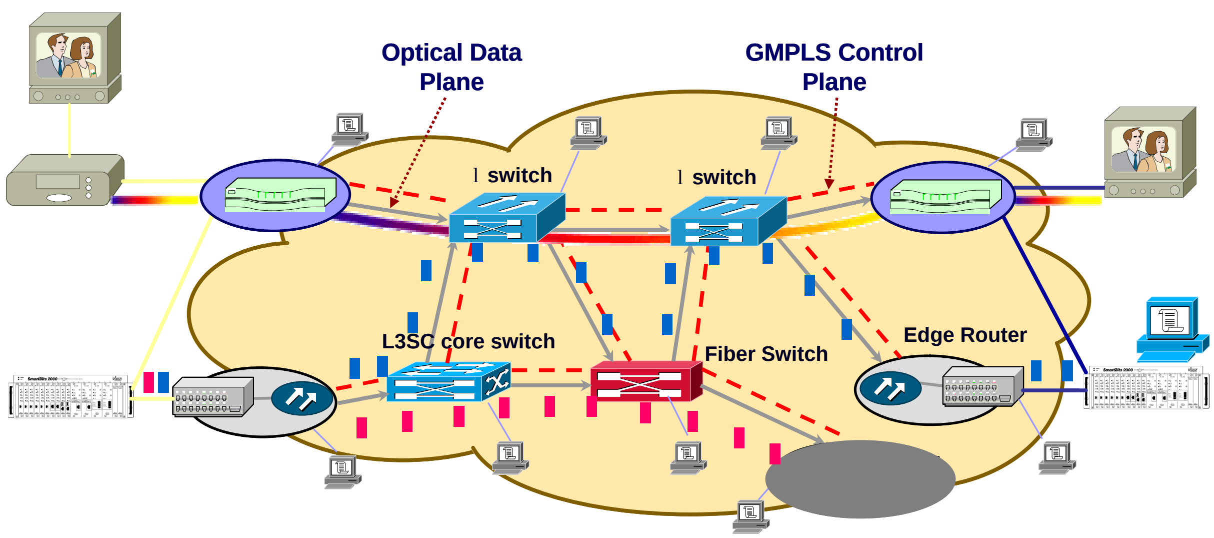


Figure 2. OPSINET network architecture.

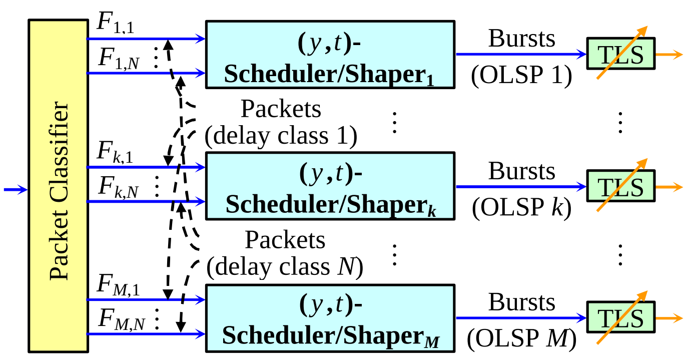
OBS, the in-band-controlled-based OCPS network was shown to provide invariably superior packet loss performance for a high priority traffic class, enabling effective facilitation of loss class differentiation.

● 子計畫二：適用於高速移動擷取網路的等化碼技術與高階調變位元軟性決策解碼技術之研究

The main difficulty for high-bit-rate transmission under high mobility is on the tracking of the fast time-varying channel characteristic due to movement. Different from other researches who mostly focus on enhancing the accuracy of the channel parameter estimation and equalization, this project aims at a pure channel-coding approach [13], i.e., to combine the channel estimation and equalization into channel code design.

The project of the first year are to develop and examine the design rule of equalizer codes in a time-varying multi-path fading environment [14], and to derive the soft bit metric of symbol-oriented high-speed modulation. Both aims have been achieved in this year.

In addition, we demonstrated a low-complex suboptimum metric prediction approach and verified the performance of our soft bit metric by simulation based on IEEE 802.11 a/g standard [15,16]. In the first part, i.e., the part of equalizer codes design, our result will be verified by simulations in next year. If the BER approximate the performance of ML decision [17], it can considerably reduce the decoding complexity. We also compare it with other known suboptimum ML approach, such as LVA [14].



Legend:
$F_{d,y}$: Packet flow of destination/loss class d and of delay class y;
OLSP : Optical Label Switched Path;
TLS : Tunable Laser Source;

Figure 3. (y,t)-Scheduler/Shaper system architecture.

● 子計畫三：光纖擷取網路技術之分析研究

There are many scheduling approaches for EPON based on dynamic bandwidth allocation (DBA) [18-21]. We have finished six scheduling mechanisms for the EPON network, and made the comparison of the system performance during specific traffic.

We designed the linear prediction algorithm to improve the bandwidth utilization and minimize the packet delay of the EPON system. The linear predictor effectively improves some efficiency of the utilization when the system approaches high traffic loading. To achieve the goal of fairness [22], we proposed QLP-LQF and QLP-EQL scheduling algorithm. The fairness of packet delay and packet blocking probability can be taken into account simultaneously.

Experimental result shows that the packet blocking probability fairness index and packet delay fairness index of data service. The LQF [23] and EQL scheme can achieve better performance in packet blocking probability fairness, but lose packet delay fairness. On the contrary, the QLP scheme [24] has better fairness in packet delay, but weak in packet blocking probability. If we consider these two indexes together, i.e. overall fairness index, the hybrid schemes would be better than LQF, EQL and QLP scheme.

We will continue the project according to the results of this year. In the study of AON MAC layer protocol and scheduling, we will study the ITU-T ASON/ATON, and PON standards; discuss the service priority of AON architecture; simulate the bandwidth utilization and packet delay of AON/EPON networks; enhance the DBA scheduling algorithm.

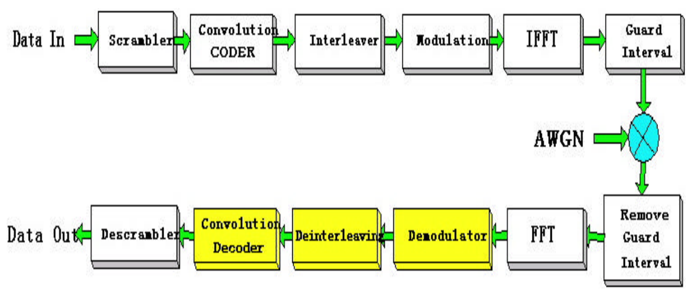


Figure 4. Data flow of subproject 2.

In the enhanced prediction-based scheduling algorithm [25] for EPON, we will check the EPON final standard to our simulation model; make a new traffic control mechanism to meet the IEEE 802.3ah [26] requirements; develop a new LAN traffic pattern for the self-similar traffic [27-29]; apply the optimum traffic pattern to the simulation programs to get the optimum results; enhance the effective prediction algorithm to improve the minimization of packet delay and maximization of bandwidth utilization.

- **子計畫四：快速行動擷取網路中之品質服務支援技術研究**

The subproject is performed with three objectives: first, the design of IP routing mechanism to support fast handoff; second, location management of mobile hosts; and third, handling of the fast handover. In this year, we develop a new handover scheme named "Speedy Handover" to enhance the performance of wireless handover. The proposed scheme makes use of IEEE 802.11 [30] RTS/CTS exchanging messages to quickly detect the movement of mobile nodes. It can improve the performance of traffic transmission during the handover period.

During handover period, packets for the mobile node maybe lost in its old foreign agent (FA), because it will attach to another new FA and has detached from the old one. We want to keep these packets and forward them to the mobile node. However, when to buffer and to forward packets are critical issues.

In our scheme, we use RTS/CTS messages exchange between FA and the mobile node to detect if the mobile node still attaches to the FA or not. The RTS/CTS messages exchange is an important method for solving hidden terminal problem in IEEE 802.11. When a FA wants to send a data packet to a mobile node, it sends a RTS message. Upon receiving a CTS message from the mobile node, the FA starts to send data packets. Since RTS/CTS messages are short, high frequent transmitted, and less affected by random loss, thus we can use them to detect the mobile node movement.

When a FA have send RTS for three times but not being responded by the mobile node, we can infer that the mobile node has left. It is a good time point to start buffering the packets for the mobile node. The time when the old FA starts forwarding packets for the mobile node is another target that we want to derive in this work. It is the critical issue of how long the mobile node can not receive any packets from begins of the handover.

In Speed Handover as shown in Figure 5, if there are some packets for the mobile node, the old FA will detect the mobile node by RTS/CTS messages. If no CTS returns, the FA buffers the incoming packets for the mobile node. After the mobile node reaches the new FA and the new FA detects the new coming mobile node. The new FA will issue a "request to forward" message to the old FA and then the old FA will forward the packets that buffered for the mobile node to the new FA.

We evaluate the proposed scheme with network simulator [31] and have the following observation. Comparing with the original mobile IP mechanism, Speedy handover features a fewer number of packet losses and a shorter handover period. The simulation

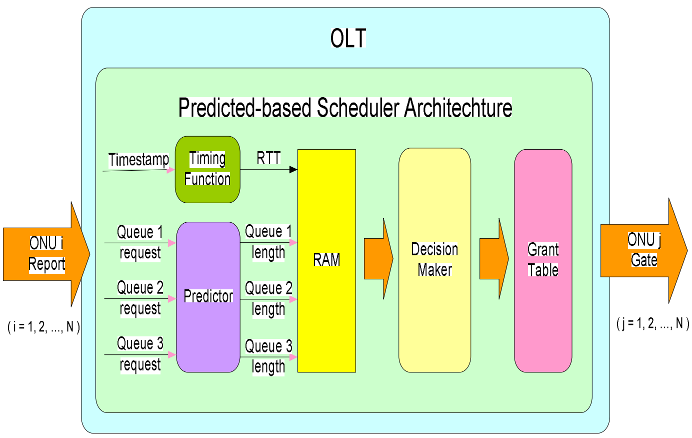


Figure 5. Predicted-based scheduler architecture.

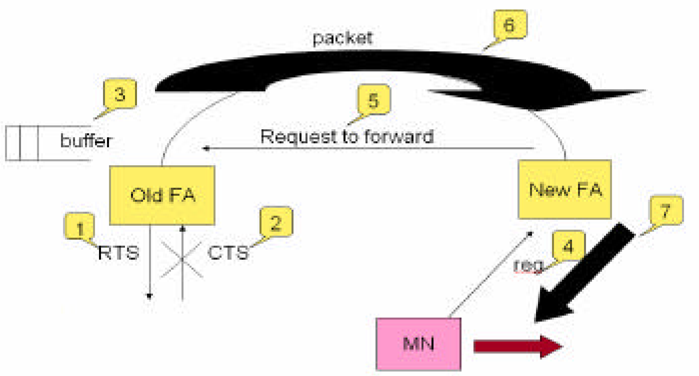


Figure 6. Messages flow of Speedy Handover scheme.

results demonstrate the effectiveness of the proposed scheme.

五、計畫執行管理與自評

在光纖都會型核心網路，由於所牽涉的技術層面相當廣，除了以我們多年在此領域的研發為基礎外，並完成了跨院、跨校、乃至跨國之技術合作。其中在交大校內整合了電工系與光電所的技術，校外則是借重台科大與工研院的特殊光元件設計與電路實作能力，在國際方面並與美國 University of Maryland**合作設計並產出高速高準確度之光纖元件。合作方式除了工研院是全職工程師進駐交大實驗室外，其他各組則是定期每個星期舉行技術討論會議。**

本計畫在今年度執行已有豐碩成果。首先，我們架設了OPSINET**雛形網路來觀察並了解光纖都會型網路的行為，並針對光纖都會型網路的特性來提供無線與**FTTx**擷取之技術合作, 接著並將研究成果投稿於國際會議與期刊，研究成果如下：**

- **四篇期刊論文**

1. *IEEE Photonic Technology Letter*：**一篇**
2. *IEEE/OSA J. Lightwave Technology*：**一篇**
3. *IEEE J. Selected Areas in communications*：**一篇**
4. *IEEE Trans. on Wireless Communications*：**一篇**

- **七篇會議論文**

1. *Conference on Optical Internet (COIN'2003)*：**一篇**
2. *IEEE/OSA European Conference on Optical Communication (ECOC'2003)*：**一篇**
3. *IEEE GLOBECOM*'2003：**兩篇**
4. *IEEE Optical Fiber Communications (OFC'2003)*：**一篇**
5. *International Conference on Informatics, Cybernetics and Systems (ICICS'2003)*：**一篇**
6. *IEEE Asia-Pacific Conference on Circuits and Systems (APCCS'2004)*：**一篇**

- **一篇審核論文**

1. *IEEE Trans. on Wireless Communications*：**一篇**

六、參考文獻

[1] M. Yuang, J. Shih, and P. Tien, "Traffic Shaping for IP-over-WDM Networks based on Optical Coarse Packet Switching Paradigm," in *Proc. European Conference on Optical Communication (ECOC)*, 2003.

[2] F. Callegati, G. Corazza, and C. Raffaelli, "Exploitation of DWDM for Optical Packet Switching with Quality of Service Guarantees," *IEEE J. Select. Areas Commun.*, vol. 20, no. 1, Jan. 2002, pp. 190-201.

[3] L. Xu, H. Perros, and G. Rouskas, "The Perspective of Optical Packet Switching in IP Dominant Backbone and Metropolitan Networks," *IEEE Comm. Mag.*, vol. 39, no. 3, March 2001, pp. 136-141.

[4] D. Hunter, *et al.*, "SLOB: A switch With Large Optical Buffers for Packet Switching," *Journal of Lightwave Technology*, vol. 16, no. 10, Oct. 1998, pp. 1725-1736.

[5] T. Battestilli, and H. Perros, "An Introduction to Optical Burst Switching," *IEEE Comm. Mag.*, vol. 41, no. 8, Aug. 2003, pp. S10-S15.

[6] M. Yoo, C. Qiao, and S. Dixit, "Optical Burst Switching for Service Differentiation in the Next Generation Optical Internet," *IEEE Comm. Mag.*, vol. 39, no. 2, Feb. 2001, pp. 98-104.

[7] V. Vokkarane, and J. Jue, "Prioritized Burst Segmentation and Composite Burst-Assembly Techniques for QoS Support in Optical Burst-Switched Networks," *IEEE J. Select. Areas Commun.*, vol. 21, no. 7, Sep. 2003, pp. 1198-1209.

[8] J. Wei, and R. McFarland, "Just-In-Time Signaling for WDM Optical Burst Switching Networks," *Journal of Lightwave Technology*, vol. 18, no. 12, Dec. 2000, pp. 2019-2037.

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

[10] M. Yoo, C. Qiao, and S. Dixit, "QoS Performance of Optical Burst Switching in IP-over-WDM Networks," *IEEE J. Select. Areas Commun.*, vol. 18, no. 10, Oct. 2000, pp. 2062-2071.

[11] E. Mannie, *et al.*, "Generalized Multi-Protocol Label Switching (GMPLS) Architecture," draft-ietf-ccamp-gmpls-architecture-03.txt, Feb. 2003, work in progress.

[12] L. Yang, Y. Jiang, and S. Jiang, "A Probabilistic Preemptive Scheme for Providing Service Differentiation in OBS Networks," in *Proc. IEEE GLOBECOM*, 2003.

[13] M. Skoglund, J. Giese and S. Parkvall, "Code design for combined channel estimation and error protection," *IEEE Trans. Inform. Theory*, vol. 48, pp. 1162-1171, May. 2002.

[14] H. Chen, K. Buckley and R. Perry, “Time-recursive maximum likelihood base sequence estimation for unknown ISI channels,” in Proc. of *34th Asilomar Conf. Circuits, Systems, Computers*, pp. TA8a14: 1-5, Nov. 2000.

[15] IEEE Std 802.11a-1999, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz band, Sept. 1999.

[16] IEEE Draft 802.11g, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz band, Draft 8.2, Apr. 2003.

[17] H. Chen, R. Perry and K. Buckley, “On MLSE Algorithm for Unknown Fast Time-Varying Channels,” *IEEE Trans. Commun.*, vol. 51, pp730-734, May. 2003.

[18] G.. Kramer and G. Pesavento, “Ethernet Passive Optical Network (EPON): Building a Next-Generation Optical Acces Network,” IEEE Commun., vol. 40, no. 2, February 2002.

[19] G. Kramer, B. Mukherjee, and G. Pesavento, “Ethernet PON (ePON): design and analysis of an optical access network,” Photo. Netw. Commun., vol. 3, no. 3, pp. 307-319, 2001.

[20] G. Kramer, B. Mukherjee, and G. Pesavento, “IPACT: A Dynamic Protocol for an Ethernet PON (EPON),” IEEE Commun., vol. 40, no. 2, pp. 74-80, 2002.

[21] G. Kramer, B. Mukherjee, S. Dixit, Y. Ye, and R. Hirth, “Supporting differentiated classes of service in Ethernet passive optical networks,” Journal of Optical Networking, vol. 1, no. 8/9, pp. 280-298, August 2002.

[22] Subir K. Biswas and Rauf Izmailov, “Design of a Fair Bandwidth Allocation Policy for VBR Traffic in ATM Networks”, IEEE/ACM Transactions on Networking, vol.8, no.2, April, 2000.

[23] D. S. Lee, “Generalized longest queue first: An adaptive scheduling discipline for ATM networks,” in Proc. IEEE INFORCOM’97, vol. 3, pp. 1096-1104, 1997.

[24] D. Liu, N. Ansari, and E. Hou, “QLP: A Joint Buffer Management and Scheduling Scheme for Input Queueed Switches,” IEEE Workshop on High Performance Switching and Routing (HPSR), pp. 29-31, May 2001.

[25] Mu Si, Ding Quanlong, and Ko Chi Chung, “Improving the network performance using perdiction based longest queue first (PLQF) scheduling algorithm,” IEEE International Conference on ATM and High Speed Intelligent Internet Symposium, vol. 22-25, pp. 344-348, April 2001.

[26] IEEE standard 802.3ah EFM

[27] A. Adas, “Traffic models in broadband networks,” IEEE Communications Magazine, vol. 35, no. 7, pp. 82-89, July 1997.

[28] W. Willinger, M. Taqqu, R. Sherman, and D. Wilson. “Self-similarity through high-variability: statistical analysis of Ethernet LAN traffic at the source level,” In Proc. ACM SIGCOMM’95, pp. 100-113, Cambridge, MA, August 1995.

[29] W. Leland, M. Taqqu, W. Willinger, and D. Wilson, “On the Self-Similar Nature of Ethernet Traffic (Extended Version),” IEEE/ACM Transactions on Networking, vol. 2, no. 1, pp. 1-15, February 1994.

[30] IEEE standard 802.11b, Std. 802.11-1999.

[31] The Network Simulator– ns2, http://www.isi.edu/nsnam/ns.