Program for Promoting Academic Excellence of Universities（Phase II）

Midterm Report

下一世代資訊通訊網路尖端技術與應用(二)－

子計畫二：光纖網路及服務品質保證技術

Advanced Technologies and Applications for Next Generation Information Networks (II) – Sub Project 2 : Optical Networking and QoS Technologies

NSC-94-2752-E-009-004-PAE

Overall Duration: April 2004 - March 2008
Annual Duration: April 2005 - March 2006

National Chiao Tung University
2006.02.28

I. BASIC INFORMATION OF THIS SUB-PROJECT (FORM 1)

Project Title: Advanced Technologies and Applications for Next Generation Information Networks (II) – Sub Project 2 : Optical Networking and QoS Technologies 下一世代資訊通訊網路尖端技術與應用(二) – 子計畫二：光纖網路及服務品質保證技術					
Serial No.: NSC-94-2752-E-009-004-PAE			Affiliation		National Chiao Tung University
Principal Investigator	Name	Maria C. Yuang 楊啟瑞	Project Coordinator	Name	Ching-Wen Chen 陳靜雯
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	Expenditures[1] (in NT$1,000)		Manpower[2]:Full time/Part time(Person-Months)	
	Projected	Actual	Projected	Actual
FY2004	8,578.290	8,113.243	36/204	36/216
FY2005	9,340.000	6,857.028	36/204	24/312
FY2006	9,237.535	-	36/204	-
FY2007	9,545.983	-	36/204	-
Overall	36,701.808	14,970.271	144/816	60/528

Notes: [1,2] Please explain large differences between projected and actual figures.

Principal Investigator's Signature:

楊啟瑞 

II. EXECUTIVE SUMMARY ON RESEARCH OUTCOMES OF THIS PROJECT (FORM 2)

1. GENERAL DESCRIPTION OF THE PROJECT: INCLUDING OBJECTIVES OF THE PROJECT (MAXIMUM 3 PAGES)

The major goal of this subproject is to explore and realize the key **Optical Networking** and **Internet QoS** technologies.

- Optical Networking

In the area of optical networking, we continue exploring the core network technology, Optical Coarse Packet Switching (OCPS) paradigm. The OCPS paradigm supports per-burst rather than per-packet switching by advocating the enforcement of traffic control and traffic engineering to achieve wavelength-based statistical multiplexing gain and QoS. Major research work includes: QoS burstification control; traffic scheduling/shaping and admission control; architectural design and performance analysis of all-optical core switches with fiber delay lines and full/partial wavelength sharing; preventive contention control and reactive wavelength contention resolution; and optical tunnel management and resource optimization. Significantly, we design and construct the 10G WDM OCPS-based IP-over-WDM experimental network, called OPSINET-II, to examine and resolve fundamental OCPS transport and QoS challenges from both the system- and network-layer perspectives. OPSINET consists of three types of nodes- edge routers, optical lambda/fiber switches (OXCs), and Optical Label Switched Routers (OLSRs) and is facilitated with an out-of-band Generalized Multi-protocol Label Switching (GMPLS) traffic engineering and control via a Fast-Ethernet network with the same topology as that of the data plane of OPSINET. Each switch/router in the data plane is connected to a GMPLS controller in the control plane, which performs either configuration for optical lambda/fiber switches, or traffic engineering and control for Optical Label Switched Routers (OLSRs).

We also aim at the design and experimentation of a 10-Gb/s QoS-enabled almost-all-Optical Packet Switching System (QOPS) for metro WDM networks. QOPS is endowed with three features beneficial to metro WDM networks. First, full wavelength sharing attains higher degrees of statistical multiplexing gains, however at the cost of requiring a large space switch size, and thus results in poor scalability. To circumvent the problem,

QOPS employs cluster-based wavelength sharing with the aim of trading off the balance between statistical multiplexing gains and scalability. Wavelengths are grouped into clusters and wavelength sharing is only allowed within the same cluster. Second, to compensate for the deterioration of loss probability resulting from the above partial wavelength sharing, QOPS adopts FDL-based single-stage downsized optical buffers. The rationale behind is that, applying few optical buffers immediately yields drastic decrease in loss probability. However, as the buffer size grows, the effectiveness is diminished. Lastly, QOPS provides QoS differentiation by means of *optical packet preemption*, with which a high-priority packet entering a full system can preempt a low-priority packet that is already in one of the delay lines. As a result, as will be shown, QOPS achieves superior packet loss probability and effectual QoS differentiation under varying traffic loads.

- QoS Technologies

In the area of Internet QoS, we focus on network and application QoS to achieve fairness and differentiation from the perspectives of layer four and above. The track on network QoS aims to provide fairness by embedding congestion control mechanisms at the source and destination hosts, i.e. at the end-to-end level; at the ingress and egress routers, i.e. at the edge sides; or inside the core routers, i.e. at the core network. Based on the underlying fair network QoS, the track on application QoS targets to provide differentiated QoS at the application layer, by putting (1) consumer-side gateways (for SOHOs and enterprises who are mostly information consumers), (2) ISP-side gateways (at the edge of an ISP), and (3) provider-side gateways (for ICPs who are mostly information providers).

2. BREAKTHROUGHS AND MAJOR ACHIEVEMENTS

- Optical Networking

In the area of optical networking, we have finished the design and construction of the OPSINET-II and presented the QOPS for metro WDM networks. The major subtasks achieved are delineated in our first figure in the appendix.

OPSINET-II supports 10-Gb/s per each wavelength, and facilitates with four newly-designed key sub-systems: (i) optical 10G core switch with FDL-based buffers, partial

wavelength sharing, and FPGA-based header processing and header/payload synchronization; (ii) multi-level ASK-based header/payload multiplexing and label swapping; (iii) routing and wavelength assignment optimizer for OPSINET-II with multi-granularity switching capabilities; and (iv) an out-of-band Generalized Multi-Protocol Label Switching (GMPLS) control network to facilitate traffic engineering. QOPS is facilitated with downsized optical buffers and optical packet preemption, QOPS achieves superior packet-loss probability and QoS differentiation.

The major achievements and breakthroughs of OCPS (OPSINET) are six-folds. First, the switch employs the partial wavelength sharing technique in combination of FDL-based optical buffers implemented by AWGs, resulting in high optical switch scalability and superlatively low packet loss probability, compared to prevailing existing optical switches. Second, the optical switch exploits two different sets of wavelength converters (WCs) at the front and back ends, most significantly, based on two different WC techniques, respectively. Consequently, such design allows low-priority packets to be preempted by newly arriving high-priority packets. Third, the switch supports dynamic QoS differentiation via threshold-based wavelength allocation with packet preemption. Such effective and superior QoS differentiation has never been proposed and implemented in any of the existing core optical switches of 10G and above. Forth, by taking advantage of the nature of OCPS, we adopt a new modulation scheme which superimposes a low-speed ASK label on top of a high-speed DC-balanced line-coded ASK payload. An old ASK label is erased by modulating the combined payload and label signal with the inverse of the received ASK label. This new approach does not require sophisticated optical components and is easy to implement. We've justified the superiority via extensive feasibility and scalability analyses through simulations and hardware experiments. Sixth, we have designed a Lagrangean-based RWA optimizer to facilitate Routing and Wavelength Assignment (RWA) in OPSINET environment including switches with different switching-granularity capabilities. RWA in an arbitrary mesh WDM network has been shown as an NP-complete problem. In this work, we propose an efficient approximation approach, called Lagrangean Relaxation with Heuristics (LRH), aimed to resolve RWA in OPSINET. The task is first formulated as a combinatorial optimization

problem in which the bottleneck link utilization is to be minimized. The LRH approach performs constraint relaxation and derives a lower-bound solution index according to a set of Lagrangean multipliers generated through subgradient-based iterations. In parallel, using the generated Lagrangean multipliers, the LRH approach employs a new heuristic algorithm to arrive at a near-optimal upper-bound solution. Numerical results demonstrate that the LRH-based RWA optimizer achieves efficient and precise RWA computation for newly arriving connections, while incurring a minimum of time and space complexity. Finally, OPSINET is facilitated with GMPLS traffic engineering (TE) and control via a Fast-Ethernet network with the same topology as that of the data plane of OPSINET. To support TE, three GMPLS control protocols (i.e., LMP, OSPF-extension, and RSVP-TE extension) are further elucidated in the operations and interworking, and an OLSR node is equipped with a traffic monitor, periodically passing traffic status information to the GMPLS controller via the μ-processor interface. In response, the GMPLS controller makes frequent updates to the TE database for determining and establishing OLSPs upon new connection requests arrive.

The major achievements and breakthroughs of QOPS are three-folds. First, QOPS employs cluster-based wavelength sharing with the aim of trading off the balance between statistical multiplexing gains and scalability. Wavelengths are grouped into clusters and wavelength sharing is only allowed within the same cluster. Second, to compensate for the deterioration of loss probability resulting from the above partial wavelength sharing, QOPS adopts FDL-based single-stage downsized optical buffers. The rationale behind is that, applying few optical buffers immediately yields drastic decrease in loss probability. Lastly, QOPS provides QoS differentiation by means of *optical packet preemption*, with which a high-priority packet entering a full system can preempt a low-priority packet that is already in one of the delay lines. As a result, QOPS achieves superior packet loss probability and effectual QoS differentiation between high- and low-priority traffic by four orders of magnitude under aggregate loads 0.7 and above.

We also focus our research efforts on building optical re-circulating loop for reconfigurable optical add/drop multiplexer (ROADM） and we investigated different modulation formation to improved the spectra efficiency. In the first part, we had successfully

designed and fabricated a 32 channel, 200 GHz spacing ROADM based on PLC (planar lightwave circuit) technology. We also finished the designed and fabrication of three port interleaver with 50GHz channel spacing, with insertion loss of only 1.5 dB. The devices are then put into the circulating loop to evaluate the transmission performance. The loop has 8 channels with each channel at 10 Gbps and the loop length is 158 km. After 1100 km of transmission, the sensitivity penalty is less than 2.5 dB. In the modulation format, we have successfully using phase modulated duobinary modulation to increase the transmission distance to 255 km with no dispersion compensation.

- QoS Technologies

In the area of Internet QoS, the major achievements and breakthroughs are divided in three areas.

(1) Network-layer fairness: this study focuses on TCP-related issues since TCP dominates the network-layer Internet. We have designed a TCP-aware load balancer, providing on-the-fly TCP path selection subject to load balancing of access links. Also, we offer bandwidth management by shaping TCP traffic at edge gateways. This study evaluates possible TCP-aware approaches through self-developed implementations in Linux, test-bed emulation, and live WAN measurement. Thirdly, we analyzed and evaluated eight typical TCP-friendly congestion control algorithms to reveal their unfair bandwidth sharing with TCP over various losses. The results indicate two of the selected schemes, TFRC and SQRT, meet the criteria under most testing scenarios. Also, from some observations, we first address the causes bringing the fault cases of schemes under heavy-losses, variant-losses, behavior-dependent losses, two-state losses, and bursty-losses, and then propose the proper strategies for an ideal scheme. On wireless network, we have proposed the Co-DRR, an integrated uplink and downlink scheduler for bandwidth management over wireless LANs. Co-DRR is an IEEE 802.11-compatible host-based fair scheduling algorithm based on the deficit round robin (DRR) and distributed-DRR (DDRR) schemes, to cooperate the uplink and downlink quantum calculations to simultaneously control uplink and downlink bandwidth.

(2) Application-layer Differentiation: To provide differential service on application-layer, this

study focuses on the design of request scheduling algorithms. First, we proposed a multiple-resource request scheduling algorithm on web-side gateway, called mQoS, for differentiating the utilization of the server resources. The mQoS scheduler consists of several sub-schedulers and a main scheduler. Each sub-scheduler manages a server resource to differentiate the utilization among the classes. By balancing resource usage and controlling traffic at gateway, the scheduling improves the total throughput and provides differential service between classes without server modification. Second, we proposed fair-queuing (FQ) based access-gateway request scheduling. This work reveals scheduling requests with FQ has the timing and ordering problems on releasing requests. Next, we propose a fair-queuing based request scheduling (FQRS) scheme, consisting of a request-based fair queuing (RFQ) discipline and a window-based service-rate controller (WRC). RFQ provides weighted fairness and bandwidth sharing while WRC controls the number of concurrent responses to provide full link utilization and reduce the user-perceived latency.

(3) System Throughput Enhancement: Besides scheduling, enhancing the system throughput is another way to improve the QoS. Because a high system throughput depends on a proper resource allocation, we first develop a network application on Intel IXP2400 network processor to investigate the impact of processor/thread allocation on system throughput. Important conclusions include: (i) given an application and algorithm, the throughput is influenced mostly by the total number of threads, namely where I and J represent the numbers of processors and threads per processor, respectively, as long as the processor utilizations are not fully utilized; and (ii) given an application, algorithm and hardware specification, an appropriate (I, J) can always be derived. Secondly, besides the development, we derived design implications through the use of Continuous-Time Markov Chain and Petri net simulations to mimic the IXP2400-like coprocessors-centric platforms, in which most of the packet processing is done in coprocessors. Our approach is unique in two aspects as compared to previous works: the concept of thread allocation scheme is introduced and addressed, and the queuing effects in memory access and processor ready queues are considered by practically modeling all the processors and threads. The simulation validates, and remedies the state-space explosion problem of the analytical model.

3. CATEGORIZED SUMMARY OF RESEARCH OUTCOMES. IN EACH RESEARCH AREA, PLEASE GIVE A BRIEF SUMMARY OF THE RESEARCH OUTCOMES ASSOCIATED WITH THE AREA. NOTE THAT THE SUMMARIES SHOULD BE CONSISTENT WITH THE STATISTICS GIVEN IN FORM 3. PLEASE LIST AND NUMBER OF EACH RESEARCH OUTCOMES IN ORDER IN APPENDIX II, AND LIST ALL THE PUBLICATIONS IN TOP CONFERENCES AND JOURNALS IN APPENDIX III.

- Optical Networking

  i. We have proposed a novel QoS Scheduler/Shaper for Optical Coarse Packet Switching IP-over-WDM Networks [B1]. The work has been published in the Optical Communications and Networking (OCN) Series of the *IEEE Journal on Selected Areas in Communications* (*JSAC 2004*). According to the chief editor's information, the journal has a very low acceptance rate, ranging from 15% to 20% among different subtopics.

  ii. In the design/construction of OPSINET-II, and its 10G optical switch, the paper for the switch architecture and technology [B14] has been published in the Optical Communications and Networking (OCN) Series of the *IEEE Journal on Selected Areas in Communications* (*JSAC 2006*). The components, such as the wavelength converter [B3] and optical filters [B4] have been published in rate-A optical devices and system journal, *IEEE Photonic Technology Letter*.

  iii. The experimentation part of OPSINET [B8] was invited as a 30-minute invited talk presented/published in *IEEE/SPIE APOC*, the largest optical communication and network conference in Asia.

  iv. In the optimization of routing and wavelength assignment for OPSINET-II, we have proposed an efficient approximation approach, called Lagrangean Relaxation with Heuristics (LRH) optimizer [B2,B7], aimed to resolve RWA in OPSINET. RWA in an arbitrary mesh WDM network has been shown as a hard NP-complete problem. Numerical results demonstrate that the LRH-based RWA optimizer achieves efficient and precise RWA computation for newly arriving connections, while incurring a minimum of time and space complexity, compared to existing famous approaches. The work has been published in the Optical Communications and Networking (OCN) Series of the *IEEE Journal on Selected Areas in Communications*, with an average of 18% acceptance rate. In addition, a simple version of the work is also published in rate-A conference, *IEEE Globecom'04*.

  v. In the design/experimentation of a metro WDM Network, we have published the 10-Gbps

QoS-enabled almost-all-Optical Packet Switching System (QOPS) [B26] in *IEEE ECOC'05*, the largest optical communication and network conference in Europe.

vi. In the design of optical re-circulating loop for reconfigurable optical add/drop multiplexer (ROADM) and the modulation formation to improved the spectra efficiency, we have published key technologies in rate-A optical devices and system journal, *IEEE Photonics Technol. Lett* [B15-B20], *Optics communications* [B5,B21], *Optics Express.* [B22], and the largest optical communication and network conference in Europe, *IEEE ECOC*'05 [B27,B28].

- QoS Technologies

i. In the areas of network/application QoS, we have published a TCP rate shaping over edge gateway in *IEEE Tran. on Computer* [B6]. We have also published three pieces of work, namely on-the-fly TCP Path Selection Algorithm in access link load balancing [B10], tunnel minimization and relay for managing VPNs [B11], and the shaping of TCP traffic at edge gateways [B12] in rate-A conference, *IEEE Globecom'04*. Besides, we submitted the taxonomy and evaluation on TCP-friendly algorithms to IEEE Network. Also, we have published a SOAP Request Scheduling for Differentiated Quality of Services in WISQ [B33].

ii. In the area of system throughput QoS, we have published our improved result on software architecture in *IEEE Computer* [B23]. A profiling and accelerating work on string matching algorithm and application are going to appear in *IEEE Communications Surveys and Tutorials* [B24]. Another three throughput accelerating works [B30,B31,B32] are published in the three *IEEE International Conferences*, respectively. An investigation in network processors for memory access intensive applications is submitted to *IEEE Micro*. Also, an analysis work on thread allocation in network processors is submitted to *IEEE Transactions on Computers*.

iii. In the system throughput QoS, we have published our improved result on software architecture in *IEEE Computer* [B23]. Another three throughput accelerating works [B30,B31,B32] are published in the three *IEEE International Conferences*, respectively.

4. A Summary of the Post-Project Plan (If there are any plan or budget adjustment for FY 2006, please provide detailed description and association with the project in Appendix I)

The 3rd year: (1) We will finish the construction of the refined system of the optical label switch router of OPSINET-II and give formal demonstrations. The refined system includes FPGA control, ASK-based label swapping system, partial/full wavelength sharing, and multistage optical FDL buffers. (2) We will accomplish the design and performance modeling and analysis of the QoS traffic control exerted at both edges and label switch routers. Results will be used in OPSINET-II construction of the last year, and displayed in paper submission, reports, and patents. (3) We will also engage the research on traffic engineering. Results will be used in the GMPLS simulator/emulator to be designed and implemented in the last year. (4) We will extend our present multiple-resource request scheduling algorithm to design a new one, which guarantees the proportionally differential user-perceived latency between users. (5) On TCP-friendly congestion control algorithm, we will propose a window-averaged congestion control algorithm to provide TCP-equivalence even under variant network. (6) On wireless scheduling algorithm, we will design a MAC-layer scheduling algorithm for base-station supporting 802.16 to provide service differentiation among five service classes specified in the standard.

The 4th year: In the last year, we will combine all previous results and demonstrate integrated accomplishments. We will finish the entire construction of 10G OPSINET-II and give formal demonstrations. The OPSINET-II experimental network includes edge routers, optical label switches, and full-grown traffic control and GMPLS-based traffic engineering. Finally, we will give formal mathematical analysis of TCP-friendly congestion control and request scheduling. In addition, we will give formal mathematical analysis of TCP-friendly congestion control and request scheduling. We will perform field trials of the 10-in-1 implementation in the real Internet environment to supplement our lab test results. We further extend our modeling work from coprocessors-centric network processors to core-centric ones such as the Intel IXP425 which handles most of the packet processing in the core processor.

5. International Cooperation Activities (optional)

III. STATISTICS ON RESEARCH OUTCOMES OF THIS PROJECT (FORM 3)

[1] Indicate the number of items that are significant. The criterion for "significant" is defined by the PIs of the program. For example, it may refer to Top journals (i.e., those with impact factors in the upper 15%) in the area of research, or conferences that are very selective in accepting submitted papers (i.e., at an acceptance rate no greater than 30%). Please specify the criteria in Appendix IV.

[2] Indicate the number of citations. The criterion for "citations" refers to citations by other research teams, i.e., exclude self-citations.

[3] Refers to the workshop and conferences hosted by the program.

[4] Includes Laureate of Nobel Prize, Member of Academia Sinica or equivalent, fellow of major international academic societies, etc.

[5] Refers to industry standards approved by national or international standardization parties that are proposed by PIs of the program.

[6] Refers to research outcomes used to provide technological services, including research and educational programs, to other ministries of the government or professional societies.

LISTING		TOTAL	DOMESTIC / INTERNATIONAL	SIGNIFICANT[1]	CITATIONS[2]	TECHNOLOGY TRANSFER
PUBLISHED ARTICLES	JOURNALS	17	D: I: 17	17	5	
	CONFERENCES	16	D: I: 16	16	0	
	TECHNOLOGY REPORTS					
PATENTS	PENDING	10	D: 4 I: 6	-		
	GRANTED	3	D: I: 3	-		
COPYRIGHTED INVENTIONS	ITEM					
WORKSHOPS/ CONFERENCES[3]	ITEM	13	D: 13 I:			
	PARTICIPANTS	849	D: 849 I:			
TRAINING COURSES (WORKSHOPS/ CONFERENCES)	HOURS					
	PARTICIPANTS					
PERSONAL ACHIEVEMENTS	HONORS/ AWARDS[4]	2	D: 2 I:			
	KEYNOTES GIVEN BY PIS	4	D: 2 I: 2			
	EDITOR FOR JOURNALS		D: I:			
TECHNOLOGY TRANSFERS	ITEM					
	LICENSING FEE					
	ROYALTY					
INDUSTRY STANDARDS[5]	ITEM					
TECHNOLOGICAL SERVICES[6]	ITEM			-	-	-
	SERVICE FEE			-	-	-

IV. List of Works, Expenditures, Manpower, and Matching Supports from the Participating Institutes (Form 4)

Serial No.: NSC-94-2752-E-009-004-PAE	Program Title: Sub-Project 2 : Optical Networking and QoS Technologies 光纖網路及服務品質保證技術

Research Item (Include sub projects)		Major tasks and objectives	Expenditures (in NT$1,000)					Manpower (person-month)					Matching Supports from the Participating Institutes (in English & Chinese)
			Salary	Seminar/ Conference-related expenses	Project-related expenses	Cost for Hardware & Software	Total	Principal Investigators	Consultants	Research/ Teaching Personnel	Supporting Staff	Total	
Sub-Project 2 光纖網路及服務品質保證技術 Optical Networking and QoS Technologies	2004	1. Design/Exploration of Optical Coarse Packet Switching (OCPS) technology; 2. Optimization of routing and wavelength assignment for OPSINET-II;	**1,797.139**	**220.000**	**1,141.466**	**2,000.000**	**5,158.605**	**48**	**12**	**36**	**12**	**108**	**2,930 (in NT$1000) 教育部台聯大**
		3. Network and application QoS;	**1,896.000**	**220.000**	**168.929**	**169.616**	**2,454.545**	**12**	**0**	**132**	**0**	**144**	
	2005	1. Design/Construction of a WDM OCPS-based experimental network, OPSINET-II, and its 10G optical switch; 2. Design/Experimentation of a 10-Gb/s QoS-enabled almost-all-Optical Packet Switching System (QOPS) for metro WDM networks;	**2,028.442**	**0**	**699.084**	**853.739**	**3,581.265**	**60**	**12**	**108**	**12**	**192**	**3,045 (in NT$1000) NCTU/CCL 交大工研院聯合研發中心**
		3. Network-layer Fairness; 4. Application-layer Differentiation; 5. System Throughput Enhancement	**1,896.000**	**240.000**	**123.528**	**409.493**	**2,669.021**	**12**	**0**	**132**	**0**	**144**	
SUM			**7,617.581**	**680.000**	**2,133.007**	**3,432.848**	**13,863.436**	**132**	**24**	**408**	**24**	**588**	**3,045**

V. APPENDIX I

DESCRIPTION OF BUDGET AND PROJECT ADJUSTMENTS FOR FY 2006

Sub-Project 2 光纖網路及服務品質保證技術
計畫編號：NSC 95-2752-E-009-004-PAE
計畫主持人：楊啟瑞教授

<table>
<tr><td colspan="2">原 核 定 補 助 情 形</td><td colspan="2">擬申請變更用途及金額情形</td></tr>
<tr><td>項　目</td><td>經　費</td><td>項　目</td><td>經　費</td></tr>
<tr><td>人事費
第 1.2 項 專任助理薪資及雇主負擔勞健保費
第 3.4 項 碩士生 192 獎助單元；博士生 660 獎助單元
第 6 項 臨時工資
第 7 項 博士後研究：2 名</td><td>
492,888

1,704,000

81,462
1,900,635</td><td>人事費
第 1.2 項 專任助理薪資及雇主負擔勞健保費
第 3.4 項 碩士生 384 獎助單元；博士生 990 獎助單元
第 6 項 臨時工資
第 7 項 博士後研究：2 名</td><td>
517,119

2,748,000

50,141
1,363,725</td></tr>
<tr><td>研究設備費</td><td>2,441,273</td><td>研究設備費</td><td>1,741,273</td></tr>
<tr><td>國外差旅費</td><td>220,000</td><td>國外差旅費</td><td>420,000</td></tr>
<tr><td>變更情形說明</td><td colspan="3">

博士後研究原申請核定 2 名，原核定之人事費為 1,900,635，扣除續聘博士後研究羅志鵬實際應使用 933,912 後，另將於 95 年 10 月中旬起新聘 1 名博士後研究員加入計畫進行研究工作，其今年度薪資估算為 429,813，所剩之餘額 536,910 轉由其他人事費使用。
專任助理薪資原核定的年資(第六年*13.5)與實際年資(第六年*3；第七年 10.5)其薪資及雇主負擔勞健保費有差額 24,231。
碩士研究生獎助單元比原核定(192 獎助單元)新增 192 獎助單元，為 384 獎助單元；博士研究生獎助單元比原核定(660 獎助單元)新增 330 獎助單元，為 990 獎助單元，需多增加研究生進行研究、分析、模擬驗證等工作。
臨時工資，需要短期支援協助測試、驗證、分析等工作之臨時人員。
原人事費由研究設備費撥入 500,000 元來支援人事薪資不足。
研究設備費撥出 500,000 元至人事費支援；撥出 200,000 至國外差旅費支援。
其他費用預算項目新增「研究空間使用費」。
國外差旅費，由研究設備費撥入新增金額 200,000，作為參訪考察下列大學、研究機構及公司之全光全光通訊網路及無線網路實驗室：
1.Stanford University, University of Maryland, University of Florida, UC Davis. 2.Telcordia Technologies, Lucent Technologies. 3. ANDevices (光纖元件公司), OPVISTA(光纖系統公司) 進行研究交流及技術討論並商討可能之研究合作，期望在尖端領域技術上有所突破；並與國內光通訊領域之相關研究單位、業界及學術單位進行交流溝通。藉此利用一學年的考察及研究，可為未來合作進行先期準備工作，希望能有更進一步的研究成果；進而發表論文、專利申請及研究計畫合作等等。
變更後人事費金額為 4,798,985；研究設備費為 1,741,273；國外差旅費金額為 420,000；總核定金額不變，仍為 9,237,535。

</td></tr>
</table>

VI. APPENDIX II

1. PUBLICATION LIST (CONFERENCES, JOURNALS, BOOKS, BOOK CHAPTERS, etc.)

- **First Year (93/04/01-94/03/31)**

Journal Papers:

[B.1] Maria C. Yuang, Po L. Tien, and J. Shih, "QoS Scheduler/Shaper for Optical Coarse Packet Switching IP-over-WDM Networks," *IEEE Journal on Selected Areas in communications*, vol. 22, no. 9, Nov. 2004, EI., SCI..

[B.2] S. W. Lee, Maria C. Yuang, Po L. Tien, and S. H. Lin, "A Lagrangean Relaxation based Approach for Routing and Wavelength Assignment in Multi-granularity Optical WDM Networks," *IEEE Journal on Selected Areas in communications*, vol. 22, no. 9, Nov. 2004, EI., SCI..

[B.3] D. Z. Hsu, S. L. Lee, P. M. Gong, Y. M. Lin, Steven S. W. Lee, and Maria C. Yuang, "High-Efficiency Wideband SOA-Based Wavelength Converters by Using Dual-Pumped Four-Wave-Mixing and an Assisted Beam," *IEEE Photonic Technology Letter*, vol. 16, no. 8, pp. 1903-1905, Aug. 2004, EI., SCI..

[B.4] Jason Jyehong Chen, "Dispersion-compensating optical digital filters for 40Gb/s Metro Add-Drop Application", *IEEE Photonic Technology Letter*, vol. 16, no. 5, May 2004, EI., SCI..

[B.5] Y. Chang, Y. Lin, Jyehong Chen, and G. Lin, "all optical NRZ-to-PRZ format transformer with an injection-locked Fabry-Perot laser diode at unlasing condition," *Optics Express*., vol. 12, no. 19, Sept. 2004, SCI..

[B.6] Huan-Yun Wei, Shih-Chiang Tsao, and Ying-Dar Lin, "Assessing and Improving TCP Rate Shaping Over Edge Gateways, " *IEEE Transactions on Computers*, vol. 53, Issue 3, pp. 259-275, March 2004, EI., SCI..

Conference Papers:

[B.7] S. W. Lee, Maria C. Yuang, and Po L. Tien, "A Lagrangean Relaxation Approach to Dynamic Routing and Wavelength Assignment for Multi-granularity Optical WDM Networks," *IEEE GLOBECOM*, Nov. 2004, EI..

[B.8] Maria C. Yuang, Po L. Tien, J. Shih, Steven S. W. Lee, Yu-Min Lin, Frank Tsai, and Alice Chen, "Optical Coarse Packet Switched IP-over-WDM Network (OPSINET): Technologies and Experiments," *IEEE/SPIE APOC*, Nov. 2004, EI..

[B.9] Z. Zhu, W. Chen, Y. Chen, J. Sun, D. Huang, and Jyehong Chen, "Cascaded-able Cline-reconfigurable Optical Add-drop Multiplexer," *IEEE ECOC*, 2004, EI..

[B.10] Ying-Dar Lin, Shih-Chiang Tsao, and Un-Pio Leong, "On-the-Fly TCP Path Selection Algorithm in Access Link Load Balancing," *IEEE GLOBECOM*, 2004, EI..

[B.11] Iwei Chen, Ying-Dar Lin, Yineng Lin, "Tunnel Minimization and Relay for Managing Virtual Private Networks," *IEEE GLOBECOM*, 2004, EI..

[B.12] Huan-Yun Wei, Shih-Chiang Tsao, Ying-Dar Lin, "On Shaping TCP Traffic at Edge Gateways," *IEEE GLOBECOM*, 2004, EI..

[B.13] Yi-Neng Lin, Chiuan-Hung Lin, Ying-Dar Lin, and Yuan-Chen Lai, "VPN Gateways over Network Processors: Implementation and Evaluation," *IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS'05)*, 2005, EI..

- **Second Year (94/04/01-95/03/31)**

Journal Papers:

[B.14] Maria C. Yuang, Po L. Tien, J. Shih, Steven S. W. Lee, Y. M. Lin, F. Tsai, and A. Chen, "Optical Coarse Packet-Switched IP-over-WDM Network (OPSINET): Technologies and Experiments," to be published in *IEEE Journal on Selected Areas in communications*, 2006, EI., SCI..

[B.15] Yu-Chang Lu, Jason (Jyehong) Chen, Kai-Ming Feng, Pao-Chi Yeh, Tzu-Yen Huang, Wei-Ren Peng, Ming-Fang Huang, and Chia-Chien Wei, "Improved SPM Tolerance and Cost-Effective Phase-Modulation Duobinary Transmission over 230 km Standard Single-Mode Fiber Using a Single Mach-Zehnder Modulator", to be published at *IEEE Photonics Technol. Lett*, 2006.

[B.16] Wei-Ren Peng, Yu-Chang Lu, Jason (Jyehong) Chen, Sien Chi, "Encoding ASK labeled CSRZ-DPSK payload by using only one dual-drive Mach-Zehnder Modulator with enhanced label performance", to be published at *IEEE Photonics Technol. Lett.*

[B.17] C.C Wei, M. F. Huang, J. H. Chen, "Enhancing the Frequency Response of Cross Polarization Wavelength Conversion", *IEEE Photonics Technol. Lett.,* pp. 1683-1685, Aug. 2005, SCI..

[B.18] K. M Feng, M. F Huang, C. C. Wei, C. Y Lai, T. Y. Lin, J. H. Chen and S. Chi, "Metro Add/Drop Network Applications of Cascaded Dispersion-Compensated Interleaver Pairs Using a Re-circulating loop", *IEEE Photonic Technol. Lett.,* pp.1349-1351, June 2005, SCI..

[B.19] G. R. Lin, Y. C. Chang, Y. H. Lin, and J. H. Chen, "All Optical Data Format Conversion in Synchronously Modulated Single-Mode Fabry-Perot Laser Diode Using External Injection-Locking Induced Nonlinear Threshold Reduction Effect", *IEEE Photonics Technol. Lett.,* pp. 1307-1309, March 2005, SCI..

[B.20] Ming-Fnag Huang, Jason (Jyehong) Chen, Kai-Ming Feng, Chung-Yu Lai, Tse-Yu Lin, and Sien Chi, "210 Km Bidirectional Transmission System with a Novel Four-Port Interleaver to Facilitate Unidirectional Amplification", *IEEE Photonic Technology Letter*, pp. 172-174, Jan., 2006.

[B.21] Peng-Chun Peng, Kai-Ming Feng, Ching-Cheng Chang, Hung-Yu Chiou, JyeHong Chen, Ming-Fang Huang, Hung-Chang Chien, and Sien Chi, "Multiwavelength Fiber Laser using S-band Erbium-Doped Fiber Amplifier and Semiconductor Optical Amplifier," *Optics communications*, vol. 259, pp. 200-203, 2006.

[B.22] Chia-Chien Wei and Jason (Jyehong) Chen, "Study of Differential Cross-Polarization Modulation in Semiconductor Optical Amplifier," *Optics Express*., vol. 13, No. 21, pp. 8442-8451, Oct. 2005, SCI..

[B.23] Ying-Dar Lin, Chih-Wei Jan, Po-Ching Lin, and Yuan-Cheng Lai, "Designing an Integrated Architecture for Network Content Security Gateways," to be published in *IEEE Computer*, 2006.

[B.24] Po-Ching Lin, Tzu-Xiang Li, Ying-Dar Lin, and Yuan-Cheng Lai, "Profiling and Accelerating String Matching Algorithms and Applications," to be published in *IEEE Communications Surveys and Tutorials*, 2006.

Conference Papers:

[B.25] Maria C. Yuang, Po-Lung Tien, Julin Shih, Steven S. W. Lee, Yu-Min Lin, Yuan Chen, Frank Tsai, and Alice Chen, "QoS Contention Control for Optical Coarse Packet Switched IP-over-WDM Network," *IEEE ITRE'05*, June 2005, Hsinchu, Taiwan, EI..

[B.26] Maria C. Yuang, Po L. Tien, J. Shih, Steven S. W. Lee, Yu-Min Lin, and Jason J. Chen, "A QoS Optical Packet-Switching System for Metro WDM Networks," *ECOC'05*, Sept. 2005, Glasgow, Scotland, EI..

[B.27] Yu-Chang Lu, Jason (Jyehong) Chen, Kai-Ming Feng, Pao-Chi Yeh, Tzu-Yen Huang, Wei-Ren Peng, Ming-Fang Huang, Chia-Chien Wei, and Sien Chi, "A cost-effective phase-modulation-enhanced duobinary modulation to improved SPM tolerance using only one Mach-Zehnder modulator," *ECOC'05*, Sept. 2005, Glasgow, Scotland, EI..

[B.28] Wei-Ren Peng, Yu-Chang Lu, Jason (Jyehong) Chen, and Sien Chi, "ASK/RZ-DPSK labeled signal generation using only one mach-zehnder modulator," *ECOC'05*, Sept. 2005, Glasgow, Scotland, EI..

[B.29] M. F Huang, C. Y. Lai, J. H. Chen, K.M. Feng, C. C. Wee, T. Y. Lin and S. Chi, "Using a novel four-port interleaver to enable unidirectional amplification in a 210 km bidirectional transmission system," *LEOS 2005*, TuU1, Sydney, Austrialia.

[B.30] Kuo-Kun Tseng, Ying-Dar Lin, Tseng-Huei Lee, and Yuan-Cheng Lai, "A Parallel Automaton String Matching with Pre-Hashing and Root-Indexing Techniques for Content Filtering Coprocessor," *16th IEEE International Conference on Application-Specific Systems*, Architectures, and Processors, Samos, Greece, July 2005, EI..

[B.31] Ying-Dar Lin, Szu-Hao Chen, Po-Ching Lin and Yuang-Chen Lai, "A Stream-based Mail Proxy With Interleaved Decompression and Virus Scanning," *IASTED SEA (Software Engineering and Applications),* Nov. 2005, Phoenix, AZ.

[B.32] Ying-Dar Lin, Po-Ching Lin, Ming-Dao Liu, and Yuan-Cheng Lai, "An Early Decision Algorithm to Accelerate Web Content Filtering," *Intl. Conf. on Information Networking (ICOIN)*, Sendai, Japan, Jan. 2006.

[B.33] Ching-Ming Tien, Cho-Jun Lee, Po-Wen Cheng, and Ying-Dar Lin, "SOAP Request Scheduling for Differentiated Quality of Services," *Web Information Systems Quality Workshop (WISQ)*, New York, November 2005.

2. PATENT LIST

- **First Year (93/04/01-94/03/31)**

[1] Po-Ching Lin, Ying-Dar Lin, and Ming-Dao Liu, "Early Blocking and Bypassing for Accelerating Web Content Filtering," ROC Pending Number: 0921-30036, 2004.

[2] Ying-Dar Lin, et al., "Method of Request Scheduling for Differentiated Quality of Service at Intermediaries," ROC pending, 2004.

[3] Ying-Dar Lin, et al., "Request scheduling for differentiated QoS at access gateway," ROC pending, 2004.

[4] Po-Ching Lin, Ying-Dar Lin, and Ming-Dao Liu, "Early Blocking and Bypassing for Accelerating Web Content Filtering," USA Pending Number: 10-731472, 2004.

[5] Ying-Dar Lin, et al., "Method of Request Scheduling for Differentiated Quality of Service at Intermediaries," USA pending, 2004.

[6] Ying-Dar Lin, et al., "Request scheduling for differentiated QoS at access gateway," USA pending, 2004.

[7] Jyehong Chen, et al., “Optical circulator”, USA Patent Number: 6757451, June 29, 2004.
[8] Ying-Dar Lin, et al., “Design of scalable techniques for quality of services routing and forwarding,” USA Patent Number: 6,738,387, May 2004.
[9] Ying-Dar Lin, et al., “Optimal contention region allocation for medium access control in multipoint-to-point networks”, USA Patent Number: 6,754,225, June 2004.

- **Second Year (94/04/01-95/03/31)**

[1] Ying-Dar Lin, et al., “Streaming-based virus scanning mechanism with on-the-fly interleaved decompression,” USA pending, 2005.
[2] Ying-Dar Lin, et al., “Using dual kernel packet queues to perform content filtering on established connections at the gateway,” USA pending, 2005.
[3] Ying-Dar Lin, et al., “Scheduling Requests with the Fair Queuing Discipline at Access Gateway,” USA pending, 2005.
[4] Ying-Dar Lin, et al., “Scheduling Requests with the Fair Queuing Discipline at Access Gateway,” ROC pending, 2005.

3. Invention List

4. List of Workshops/Conferences Hosted by the Project

- **First Year (93/04/01-94/03/31)**

[1] 2004/07/09-12 – Dr. Tingye Li, U.S. National Academy of Engineering and WDM Founder
Topic：WDM Technologies in Optical Networks
(Participants：30) (Maria C. Yuang)
[2] 2004/10/11-13 – Seminar, Prof. Biswanath Mukherjee, UC Davis
Topic：Optical Access Networks / Resilient Mesh Networks / Traffic Grooming in Mesh Optical Networks
(Participants：40) (Maria C. Yuang)
[3] 2004/07/16 - WLAN SOHO Router Benchmarking Workshop
(Participants：75) (Ying-Dar Lin)
[4] 2004/08/26 – Networking Test Technique Workshop
(Participants：115) (Ying-Dar Lin)
[5] 2004/12/6~10 – Asia-DSL Plugfest and Forum
(Participants：140) (Ying-Dar Lin)
[6] 2005/01/27 – Security Products Benchmarking Workshop
(Participants：90) (Ying-Dar Lin)
[7] 2005/03/22 – 第一次 NBL SIG 座談會 (Participants：32) (Ying-Dar Lin)

- **Second Year (94/04/01-95/03/31)**

[1] 2005/08/03 – IEEE Communication Society’s Elect President, Dr. Nim Cheung
Topice：Technology and Architecture Trends in Optical Networking
(Participants：30) (Maria C. Yuang)
[2] 2005/04/13 – VoIO Plugfest and IOT Lab development panel (Participants：16) (Ying-Dar Lin)
[3] 2005/06/20-24 – VoIP Plugfest and Testing workshop (Participants：125) (Ying-Dar Lin)

[4] 2005/07/27 – VoWLAN performance testing workshop (Participants：52) (Ying-Dar Lin)
[5] 2005/10/06 – Layer 2/3 New Switch testing Spec. and benchmarking workshop (Participants：54) (Ying-Dar Lin)
[6] 2006/01/25 – NBL Workshop on Voice over WLAN Public Benchmarking and Technology Developing (Participants：50) (Ying-Dar Lin)

5. List of Personal Achievements of the PIs

- **First Year (93/04/01-94/03/31)**

[1] 2004/11/07 楊啟瑞教授應 IEEE APOC'04 國際會議邀請專題演講
Topic：Optical Coarse Packet Switched IP-over-WDM Network (OPSINET): Technologies and Experiments
[2] 2004/07/21 林盈達教授應資策會邀請專題演講及座談
Topic: 台灣往通產業總體檢-產品技術面
[3] 2004/08/12 林盈達教授應 Fortinet 公司邀請專題演講
Topic: Trends in Network Security Product Development
[4] 2004/09/02 林盈達教授應 IFPI 倫敦總部邀請專題演講
Topic: P2P Application Behaviors
[5] 林義能, 林權宏, 林盈達, "92 學年度全國大學院校嵌入式軟體設計競賽佳作" (2004)
[6] 與工研院合作研發"先進光通訊網路交換技術"獲經濟部九十三年度科技專案創新技術獎

6. List of Technology Transfers

7. List of Technology Services

VII. APPENDIX III

LIST OF PUBLICATIONS IN "TOP" JOURNALS AND CONFERENCES (LIMIT TO 3-5)

1. The criteria for top journals and conferences should be defined and stated briefly at the beginning of this section.
2. Please provide electronic files for these publications

IEEE Journal on Selected Areas in communications.

[Impact factor = 2.64, ranked 2 of 57 in subject categories Telecommunication].

1. Maria C. Yuang, Po L. Tien, and J. Shih, "QoS Scheduler/Shaper for Optical Coarse Packet Switching IP-over-WDM Networks," *IEEE Journal on Selected Areas in communications*, vol. 22, no. 9, Nov. 2004, EI., SCI..
2. S. W. Lee, Maria C. Yuang, Po L. Tien, and S. H. Lin, "A Lagrangean Relaxation based Approach for Routing and Wavelength Assignment in Multi-granularity Optical WDM Networks," *IEEE Journal on Selected Areas in communications*, vol. 22, no. 9, Nov. 2004, EI., SCI..
3. Maria C. Yuang, Po L. Tien, J. Shih, Steven S. W. Lee, Y. M. Lin, F. Tsai, and A. Chen, "Optical Coarse Packet-Switched IP-over-WDM Network (OPSINET): Technologies and Experiments," to be published in *IEEE Journal on Selected Areas in communications*, 2006, EI., SCI..

IEEE Photonic Technology Letter

[Impact factor = 2.55, ranked 9 of 54 in subject categories Optics].

1. D. Z. Hsu, S. L. Lee, P. M. Gong, Y. M. Lin, Steven S. W. Lee, and Maria C. Yuang, "High-Efficiency Wideband SOA-Based Wavelength Converters by Using Dual-Pumped Four-Wave-Mixing and an Assisted Beam," *IEEE Photonic Technology Letter*, vol. 16, no. 8, pp. 1903-1905, Aug. 2004, EI., SCI..
2. Jason Jyehong Chen, "Dispersion-compensating optical digital filters for 40Gb/s Metro Add-Drop Application", *IEEE Photonic Technology Letter*, vol. 16, no. 5, May 2004, EI., SCI..
3. Yu-Chang Lu, Jason (Jyehong) Chen, Kai-Ming Feng, Pao-Chi Yeh, Tzu-Yen Huang, Wei-Ren Peng, Ming-Fang Huang, and Chia-Chien Wei, "Improved SPM Tolerance and Cost-Effective Phase-Modulation Duobinary Transmission over 230 km Standard Single-Mode Fiber Using a Single Mach-Zehnder Modulator", to be published at *IEEE Photonics Technol. Lett*, 2006.
4. Wei-Ren Peng, Yu-Chang Lu, Jason (Jyehong) Chen, Sien Chi, "Encoding ASK labeled CSRZ-DPSK payload by using only one dual-drive Mach-Zehnder Modulator with enhanced label performance", to be published at *IEEE Photonics Technol. Lett.*
5. C.C Wei, M. F. Huang, J. H. Chen, "Enhancing the Frequency Response of Cross Polarization Wavelength Conversion", *IEEE Photonics Technol. Lett.*, pp. 1683-1685, Aug. 2005, SCI..
6. K. M Feng, M. F Huang, C. C. Wei, C. Y Lai, T. Y. Lin, J. H. Chen and S. Chi, "Metro Add/Drop Network Applications of Cascaded Dispersion-Compensated Interleaver Pairs Using a Re-circulating loop", *IEEE Photonic Technol. Lett.*, pp.1349-1351, June 2005, SCI..
7. G. R. Lin, Y. C. Chang, Y. H. Lin, and J. H. Chen, "All Optical Data Format Conversion in Synchronously Modulated Single-Mode Fabry-Perot Laser Diode Using External

Injection-Locking Induced Nonlinear Threshold Reduction Effect", *IEEE Photonics Technol. Lett.,* pp. 1307-1309, March 2005, SCI..

8. Ming-Fang Huang, Jason (Jyehong) Chen, Kai-Ming Feng, Chung-Yu Lai, Tse-Yu Lin, and Sien Chi, "210 Km Bidirectional Transmission System with a Novel Four-Port Interleaver to Facilitate Unidirectional Amplification", *IEEE Photonic Technology Letter*, pp. 172-174, Jan., 2006.

IEEE Transactions on Computers

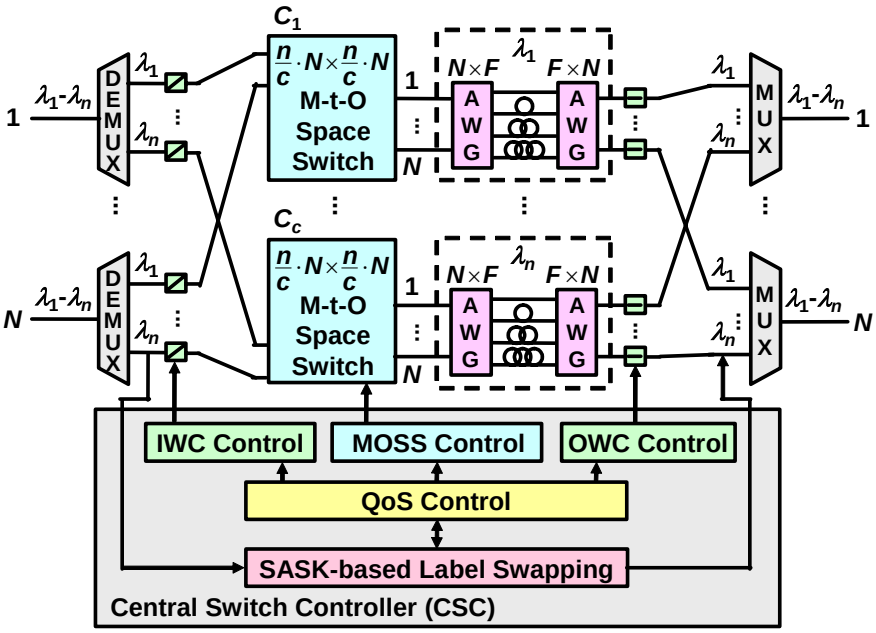
[Impact factor = 2.42, ranked 4 of 44 in subject categories Computer science, Hardware & architecture].

1. Huan-Yun Wei, Shih-Chiang Tsao, and Ying-Dar Lin, "Assessing and Improving TCP Rate Shaping Over Edge Gateways, " *IEEE Transactions on Computers*, vol. 53, Issue 3, pp. 259-275, March 2004, EI., SCI..

VIII. APPENDIX IV

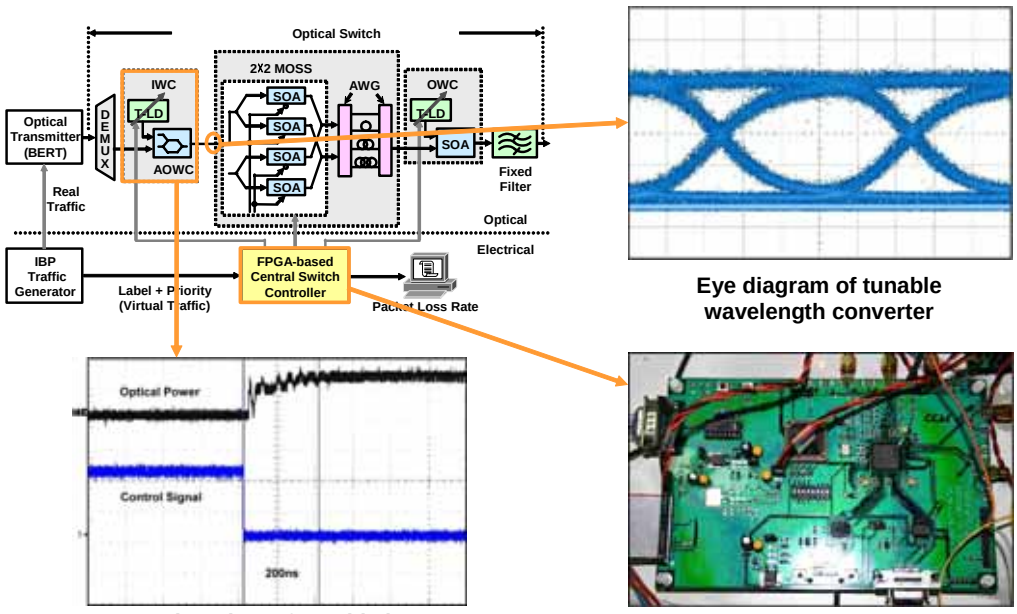
SLIDES ON SCIENCE AND TECHNOLOGY BREAKTHROUGHS (TWO SLIDES FOR EACH BREAKTHROUGH)

QOPS- System Architecture



1

QOPS- Experimental Results



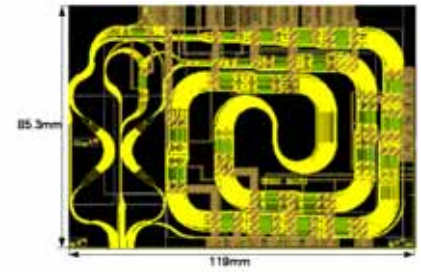
Eye diagram of tunable wavelength converter

Transient time of tunable laser-based wavelength converter

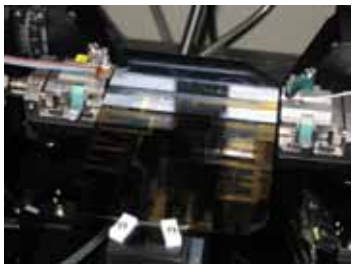
Central switch controller module

2

ROADM and Three-port interleaver Design



(a)可重新置換的交換節點的元件光罩

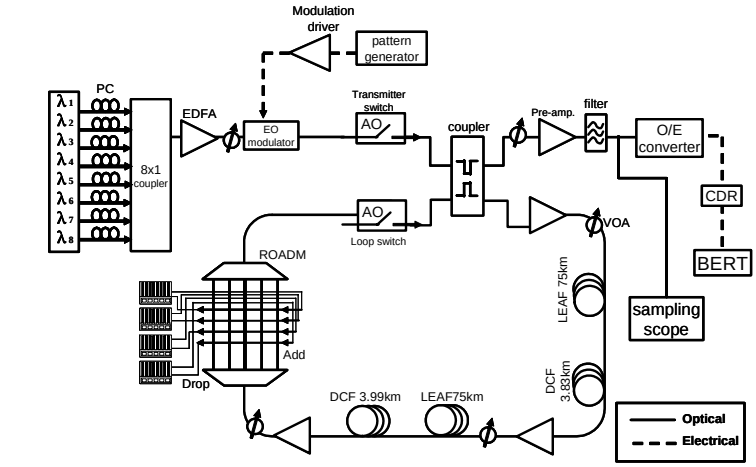


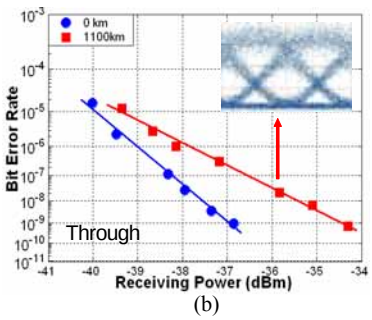
(b)對光與封裝中的元件

(c)裝上電控制線路後可由電腦直接控制光通道的add and drop

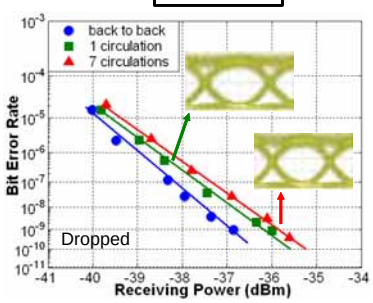
3

八通道10Gbps的光重新環繞迴圈實驗





(b)

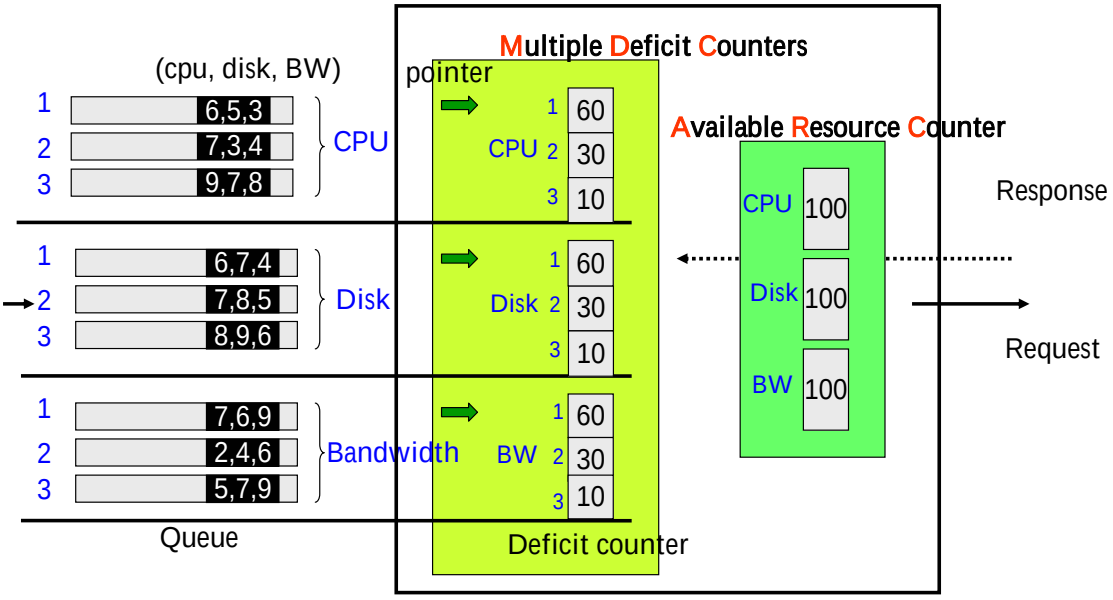


(c)

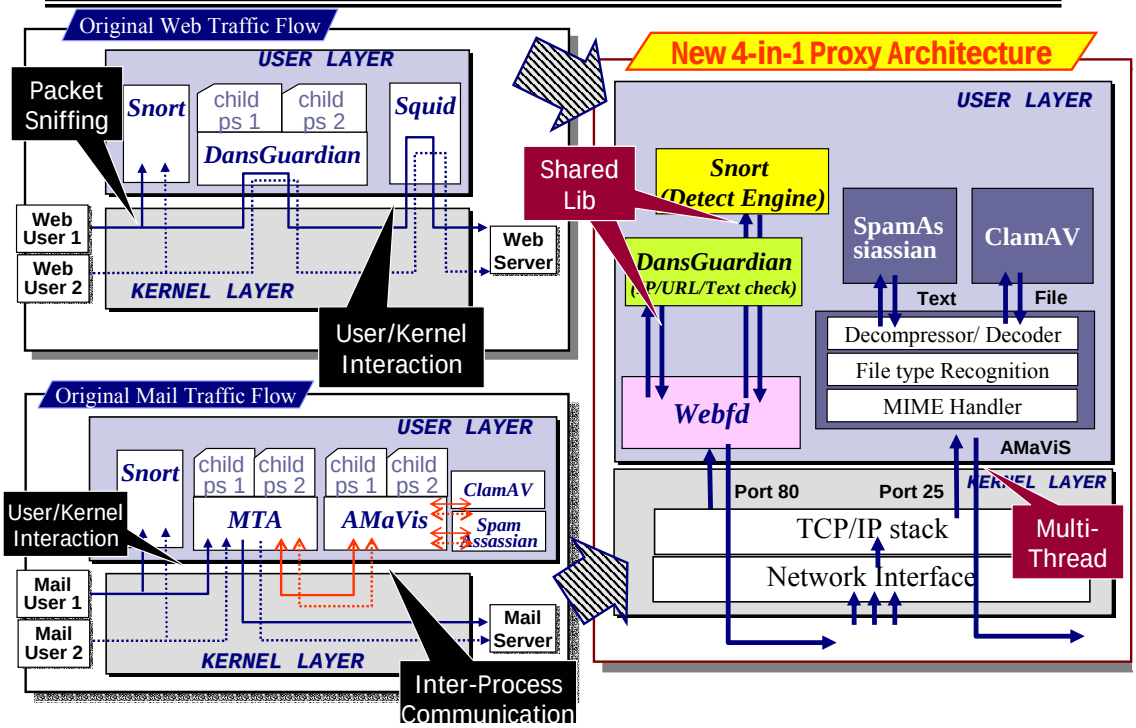
4

Application-layer Differentiation: Multiple-Resource Request Scheduling on Website Gateway

- Multi-resource requests scheduled by multi-counter DRR



System Performance: 4-in-1 Proxy Architecture



IX. APPENDIX V: SELF-ASSESSMENT

PROJECT TITLE: 子計畫二：Optical Networking and QoS Technologies

	ASSESSMENT SUBJECT	SCORE (1~5, LOW TO HIGH)
PROJECT'S CONTENTS & PERFORMANCE	Importance & Innovation of the Project's Major Tasks	5
	Clarity and Presentation of the Report	5
	Viability of the Project's Approaches & Methodologies	5
	Principle Investigator's Competence for Leading the Project	5
	Interface & Integration with the main project	
	Interface & Integration with other Sub-Projects	
	Manpower & Expenditures	
PROJECT'S RESULTS	Contribution in Enhancing the Institute's International Academic Standing	5
	Impact on Advancing Teaching or on Technology Development	5
	OVERALL	

Program Reviewer's Signature: Prof. Lui Sha