行政院國家科學委員會專題研究計畫　成果報告

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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：NSC94-2213-E-009-015

執行期限： 94 年 8 月 1 日至 95 年 7 月 31 日

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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)下無線網際網路之服務品質保證(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

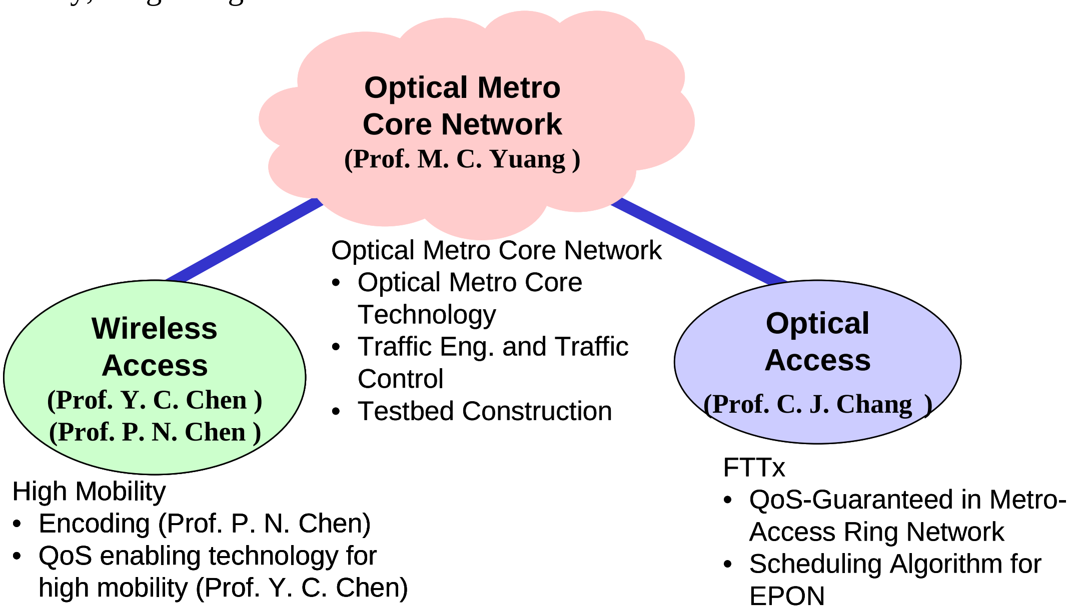


Figure 1. Relationship between sub-projects.

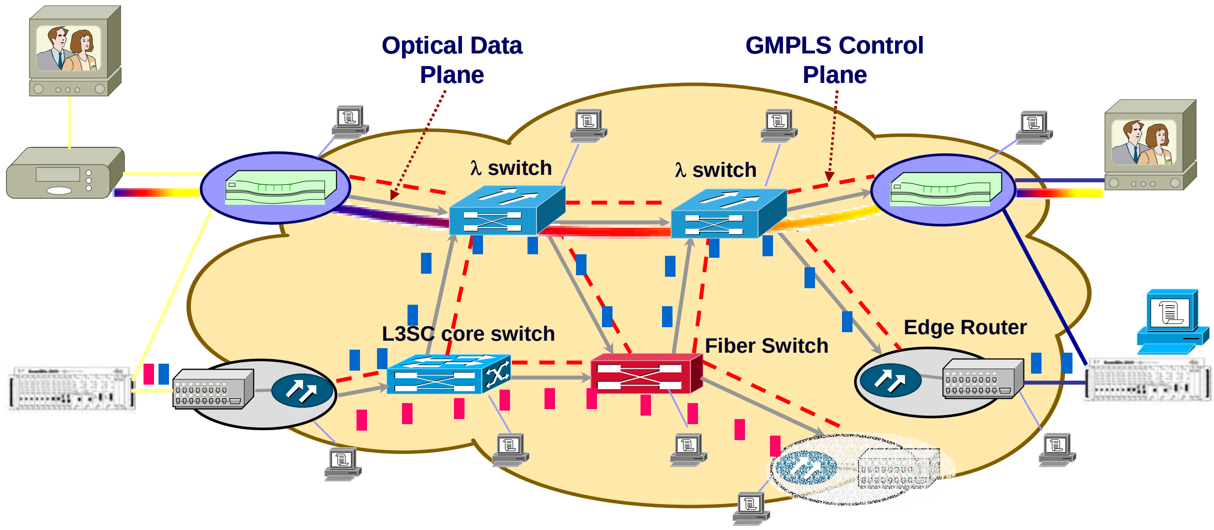


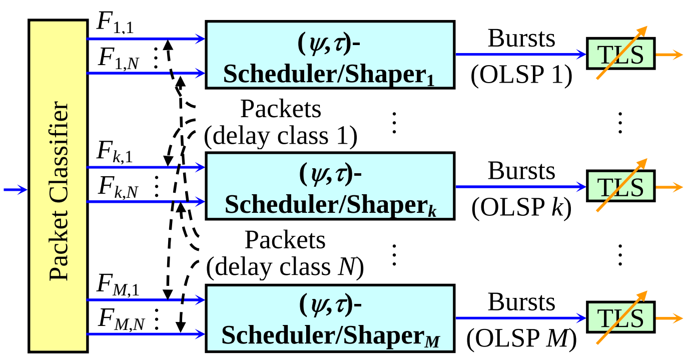
Figure 2. OPSINET network architecture.

smoothly support the seamless real-time multimedia streaming.

四、成果與討論

● 子計畫一：光纖都會核心網路技術研究

In the first year, 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] and OBS [3], 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



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

Figure 3. (ψ,τ)-Scheduler/Shaper system architecture.

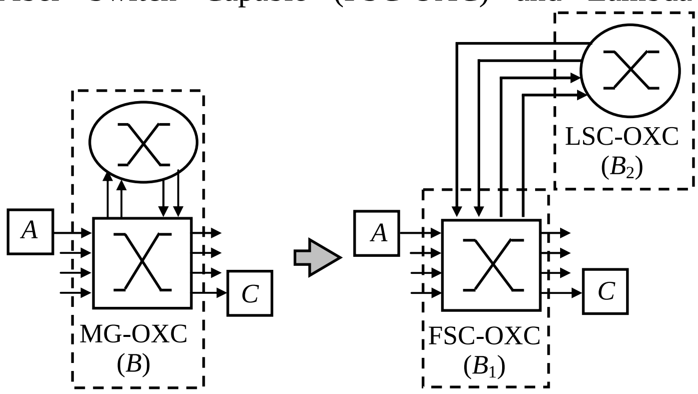
facilitate traffic engineering, OPSINET is augmented with an out-of-band Generalized Multiprotocol Label Switching (GMPLS) [4] control network. In sequel, we focus on QoS burstification control of OPSINET.

The QoS burstification control of OPSINET is performed by a QoS-enhanced traffic control scheme, called (ψ,τ)-Scheduler/Shaper, where ψ and τ are the maximum burst size (packet count) and maximum burst assembly time, respectively. Essentially, (ψ,τ)-Scheduler/Shaper is a dual-purpose scheme. It is a scheduler for packets, abbreviated as **(ψ,τ)-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 **(ψ,τ)-Shaper**, which determines the sizes and departure times of bursts.

To provide delay class differentiation, for IP packet flows designated with delay-associated weights, (ψ,τ)-Scheduler performs packet scheduling and assembly into bursts based on their weights and a *virtual window* of size ψ. The Scheduler exerts simple FIFO service within the window and assures weight-proportional service at the window boundary. The scheme provides different classes of 99% delay bound guarantees. To provide loss class differentiation, (ψ,τ)-Shaper facilitates traffic shaping with a larger burst size (ψ) assigned to a higher priority class. Furthermore, we conduct network-wide simulations to draw loss performance comparisons between OCPS and JET-based OBS [3]. Simulation results demonstrated that, due to the near-far problem [5], OBS undergoes several orders of magnitude increase in packet loss probability for Class *H* traffic particularly under a smaller burst size. As opposed to 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.

In the second year, our major traffic engineering challenge in such WDM networks has been the Routing and Wavelength Assignment (RWA) problem [6,7]. The problem deals with routing and wavelength assignment between source and destination nodes subject to the wavelength-continuity constraint [8] in the absence of wavelength converters. It has been shown that RWA is an NP-complete problem [8]. Numerous approximation algorithms [6,7] have been proposed with the aim of balancing the trade-off between accuracy and computational time complexity. In general, some algorithms [9,10] focused on the problem in the presence of sparse, limited, or full-range wavelength converters. Some others made an effort to either reduce computational complexity by solving the routing and wavelength assignment sub-problems separately [8], or increase accuracy by considering the two sub-problems [11] jointly. However, with the multi-granularity switching capability taken into consideration, most existing algorithms become functionally or economically unviable.

Our aim is to resolve the RWA problem in multi-granularity WDM networks particularly with Fiber Switch Capable (FSC-OXC) and Lambda Switch Capable (LSC-OXC) devices. It is worth mentioning that, as shown in Figure 4, an MG-OXC node is logically identical to an individual FSC-OXC node in conjunction with an external separated LSC-OXC node. For ease of illustration, we adopt the separated node form throughout the rest of the report. The problem is in short referred to as RWA^+.



(a) An MG-OXC node (b) FSC-OXC and LSC-OXC nodes

Figure 4. A combined MG-OXC node and its logically identical separated node form.

In this sub-project, we have resolved a RWA^+ problem using the LRH method, which is a Lagrangean Relaxation based approach augmented with an efficient primal heuristic algorithm. With the aid of generated Lagrangean multipliers and lower bound indexes, the primal heuristic algorithm of LRH achieves a near-optimal upper-bound solution. A performance study delineated that the performance trade-off between accuracy and convergence speed can be manipulated via adjusting the Quiescence Threshold parameter in the algorithm. We have drawn comparisons of accuracy and computation time between LRH and the Linear Programming Relaxation (LPR)-based method, under three random networks. Experimental results demonstrated that, particularly for small to medium sized networks, the LRH approach using a termination requirement profoundly outperforms the LPR method and fixed-iteration-based LRH, in both accuracy and computational time complexity. Furthermore, for large sized network (ARPA network), numerical results showed that LRH achieves a near optimal solution within acceptable computation time. The above numerical results justify that the LRH approach can be used as a dynamic RWA^+ algorithm for small to medium sized networks, and as a static RWA^+ algorithm for large sized networks.

In the last year, we center on the design and experimentation of a high-performance MAC schemes achieving superior bandwidth access efficiency and different QoS guarantees in the ring topology. The future optical Metropolitan Area Networks (MANs) are expected to employ optical packet switching to cost-effectively support a wide range of heterogeneous traffic with different time-varying and high bandwidth demand. Optical Wavelength Division Multiplexing (WDM) has been highly successful in providing very high capacity in the backbone of the Internet. SONET has provided reliable circuit switched data transfer within metropolitan areas, as well as data transfer from local networks to the backbone. According to the increasing portion of bursty data and multimedia traffic, the design focus of the networks is an efficient, flexible, and reliable optical packet switched for metro area networks.

Network nodes require dynamic capability to access a ring network flexibly and effectively. Nodes are generally equipped with tunable transmitters and tunable receivers [12-15]. Some networks adopt fixed transmitter and receiver arrays to achieve this objective [14,16,17]. Advances in fast tunable lasers suggest that laser tuning times within several nano-seconds are commercially available, enabling fast and dynamic access to network resources. A Tunable Transmitter - Fixed Receiver (TT-FR) based bi-directional WDM ring network [12] has been implemented. The DQBR MAC (modified from IEEE 802.16 DQDB) exhibits various performance benefits, including high utilization and fairness, but requires a lot of counters to monitor the network status, leading to scalability problems. Additionally, their prototype network still suffers from the fairness problem while the traffic load exceeds 0.7.

In this work, we have proposed a high-performance optical packet-switched metro WDM ring network, called HOPSMAN. Equipped with novel medium access control, HOPSMAN provides bandwidth efficiency, access delay, fairness, and bursty traffic adaptation. We have performed simulations on a ring network with three types of

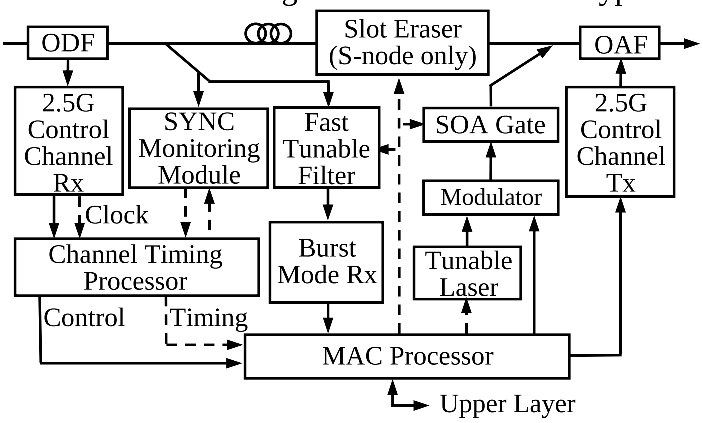


Figure 5. HOPSMAN node architecture.

nodes. Simulation results demonstrate that the MAC scheme enables high bandwidth efficiency and fair bandwidth allocation under heavy loads. We also constructed an experimental ring testbed to demonstrate the viability and superiority of HOPSMAN (see Figure 5).

- 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 [18], 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 [19], 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 [20,21]. 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 [22], it can considerably reduce the decoding complexity. We also compare it with other known suboptimum ML approach, such as LVA [19].

Based on the result of the first year, the aims of the second year are to design channel codes which have been considered the statistics properties of fading channels. The main technology obstacle for

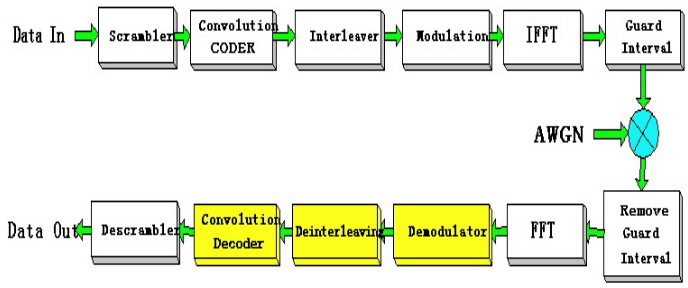


Figure 6. Data flow of subproject 2.

high-bit-rate transmission under high mobility is the seemingly highly time-varying channel characteristic due to movement; such a characteristic enforces the dependence between consecutive symbols, and further effects the difficulty in compensating the intersymbol interference. In principle, the temporal channel memory can be eliminated by an intersymbol space longer than the channel memory spread. An example is the IEEE 802.11a standard, in which 0.8-μs "intersymbol space" is added between two consecutive 3.2-μs OFDM symbols to combat any delay spread less than 800 nano seconds. In order to take advantage of the circular convolution technique, the 0.8-μs "intersymbol space" is designed to be the leading 0.8-μ portion of the 3.2-μs OFDM symbol, which is often named the *cyclic prefix* [23]. Motivated by this, we experiment on a different view in the neutralization of channel memory, where the "intersymbol space" may be of use to enhance the system performance.

In order to examine the performance of our proposed system, we tempted to establish the capacity of the time-varying fading channel experimented. There have been several publications investigating the capacity of fading channels. The capacity of the flat Rayleigh fading channel has been studied in [24] under the assumption that the state of channel fading is perfectly known to both the transmitter and the receiver. While neither the transmitter nor the receiver knows the channel state information (CSI), investigation of the capacity of memoryless Rayleigh fading channels can be found in [25].

In this year, there are two questions on which we concentrate. The first is to experiment on a different view in the neutralization of channel memory, where

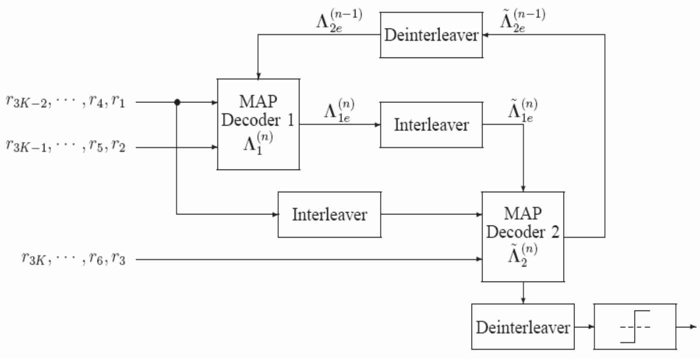


Figure 7. Iterative MAP algorithm.

the "intersymbol space" may be of use to enhance the system performance. The second question that the research aims at is that what the *capacity* of a time-varying channel, like Gauss-Markov [26,27], is. Seldom publications have been emerged in the capacity study of Gauss-Markov channels. The understanding of this quantity helps the researchers to be fully understood of the gap between a transmission scheme and the underlying limit.

Based on the result of last year, the aims of this year are to design channel codes which have been considered the statistics properties of fading channels. In this work, we take the PCCC code and its respective iterative MAP decoder as a test vehicle to experiment on the idea that the *temporal channel memory* can be weakened to *nearly blockwise time-independence* by the insertive transmission of "random bits" of sufficient length between two consecutive blocks, for which these "random bits" are actually another parity check bits generated due to interleaved information bits. The simulation results show that the metrics derived based on blockwise independence with 2-bit blocks periodically separated by a *single* parity-check bit from the second component RSC encoder perform close to the CSI-aided decoding scheme, and is at most 0.9 dB away from the Shannon limit at $BER = 2 \times 10^{-4}$ when $h_0 = 1$ and $\sigma_v^2 = 0.001$. The result of the first part has been prepared for submission to IEEE communication letters. A natural future work is to extend the channel memory to higher order, and further examine whether the same idea can be applied to obtain well-acceptable system performance.

In the second part, we have remarked on four different definitions of channel capacities according to the transmitter/receiver with/without channel state information. We then turn to the derivation of the independent bounds for the channel capacity without CSI in both transmitter and receiver. We then found that if there is no LOS signal existing, the capacity of the blind-CSI system will be reduced to zero.

On the last year, we demonstrate the well performance of PCCC code by considering the statistical properties of Gauss-Markov fading channels by simulations based on the MAP metric derived in last year. It proves the feasibility of our idea that the memory of channels can be weakened to blockwise independence by inserting “random bits” between two consecutive blocks. On the second part of this work, we derive the pairwise error probability as a function of the criterion for use of the simulated annealing algorithm. By the simulated annealing algorithm, we construct codes that have better WER performance than those obtained from [28]. Our designed codes provide a coding gain of about 3.5 dB and 6 dB on the Gauss-Markov channels with channel memory orders 1 and 2 respectively over those given in [28] at WER= 10^{-2}. During the process to obtain this criterion, we found that the complicate characteristic of the channel increases the operations needed for code search drastically. Even though we have performed some reductions on the criterion to speed up the algorithm, it still takes a long time to search for good codes. A natural future work will be to further speed up the algorithm by simplifying the code search criterion.

● 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) [29-32]. In this subproject, we focus on three fileds as follows.

The first one is fair scheduling schemes for non-real-time service in EPON access network. We first proposed a scheduling method that is suitable for EPON access network, and three classes of service are considered, i.e. real-time voice, real-time video, and non-real-time data service. For real-time service, the delay-considered scheduling is introduced, the average delay of voice packets and is considered. And then, for non-real-time service, the fairness-considered scheduling method is discussed. We proposed two scheduling algorithms, Hybrid EQL-QLP and Hybrid LQF-QLP schemes, to obtain the overall fairness which combines the fairness of packet delay with fairness of packet blocking probability. Each scheme is combined by two basic sub-schemes. We use a queue length threshold to be an adjusting parameter. The basic requirement of our scheme is to maintain the delay bound of voice service and to improve the fairness of packet delay and fairness packet blocking probability for non-real-time data service.

Simulation results show that, by adopting proposed scheme, the average packet delay of voice service can guaranteed and the overall fairness of data service can be improved compare with traditional scheduling schemes, such as LQF[33], and QLP[34]. It also shows that the Hybrid LQF-QLP scheme has better performance than Hybrid EQL-QLP scheme. We conclude that the proposed scheme can not only maintain the QoS criterion of voice service, but also support the good fairness for non-real-time service in terms of packet delay and packet blocking probability.

We also proposed a prediction-based scheduler architecture (see Figure 9). A moving average method is chosen to estimate the number of arrived packets during a cycle. The results show that the prediction error results in a slightly decreased throughput, but will decrease the average packet delay especially in

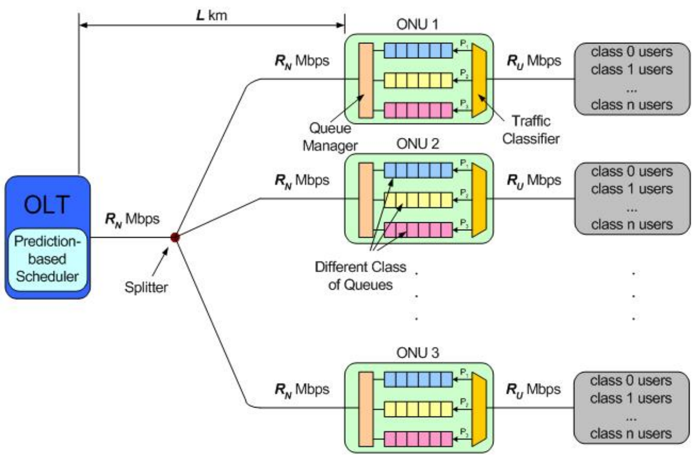


Figure 8. EPON structure.

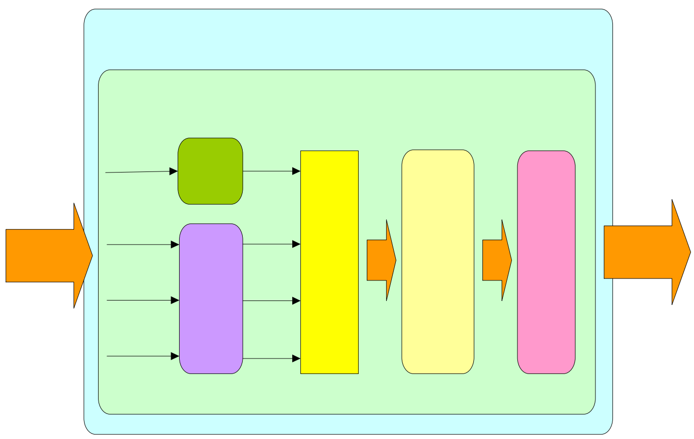


Figure 9. Predicted-based scheduler architecture.

voice service. With the decreased delay, the maximum cycle time can be extended to improve the performance of system throughput.

In the simulation, we can see that the moving average method can not perfectly estimate the behavior of self-similar traffic. Because the variation of self-similar traffic is large, the predictor will over estimate frequently. However, the prediction of real-time traffic results in an extended cycle time. When the cycle time is extended, the system throughput can be improved more, compare with non-prediction-based scheme. Thus, we believe the moving average is a cost-effective solution to improve the system throughput in EPON environment.

The second field is QoS-promoted dynamic bandwidth allocation (Q-DBA) for ethernet passive optical networks. We proposed a Q-DBA method to allocate bandwidth with three classes of packets, voice, video, and data based on the priorities from the highest to the lowest step by step. Thus, Q-DBA sets the voice packets to be the first priority, and the video packets' priority is changed from the fifth priority into the third priority when the video packets' delay criterion will be violated at the end of next cycle. To sustain the video dropping probability, the priority of video packets can be raised to the second priority in further. Although data packets do not have any delay constraint, they still should not be sacrificed. The Q-DBA also raises the priority of data packets, which is from the sixth priority to the fourth priority when the waiting time of data packet exceeds the waiting bound. It can avoid the data packets from being in the starvation condition. Furthermore, the bandwidth of the fiber link is totally allocated to make the system fully utilized.

The simulation results show that the Q-DBA has a better performance than DBAM and the QoS of voice packets are also fully guaranteed. The delay time of video packets is almost below the video delay criterion and the dropping probability of video packets is also guaranteed. Besides, the data packets are transmitted without being in the starvation condition. Above that, the Q-DBA can support most of the system load without violating the QoS requirements. In addition, with the development of WDM, the proposed Q-DBA method may be adapted to manage the resource in the EPONs, and customers can get the most benefits.

The third field is computation-efficient algorithms for dynamic traffic grooming in metro-access ring network. In this field, we solve the problem of dynamic traffic grooming and wavelength assignment in metro-access ring network. The goal is to effectively maximize the utilization efficiency of the wavelength used and reduce the new call blocking rate. We present the ILP formulation for the problem. In order to solve this problem, we propose STGA algorithm to obtain the optimal solution. However, the STGA algorithm is infeasible due to its computation complexity. Alternatively, we propose a heuristic algorithm-based HTGA algorithm. Although the HTGA algorithm is a suboptimal solution, the computation complexity of the HTGA is much lower than that of the STGA.

From the simulation comparisons between the two algorithms in the same environment, we can summarize the pros and cons of the STGA and HTGA algorithm. For STGA algorithm, the advantage is that it can attain an optimal solution while the disadvantage is that the computation complexity and the number of rearranged lightpaths are large. On the other hand, for HTGA algorithm, the advantage is that the computation complexity and the number of rearranged lightpaths are small while the disadvantage is that it just can obtain sub-optimal solution. However, the disadvantage of the HTGA algorithm is accepted because the gap of the throughput utilization is just less than 10%. Therefore, the HTGA algorithm is a feasible and attractive algorithm.

Besides, another advantage of the HTGA can be observed in various environments. Simulation results show that the throughput gap between the two algorithms is no more than 10% in all the three scenarios. Thus, we can conclude that the performance of the HTGA algorithm does not deteriorate substantially in various network configurations, including different network size, mean service time, and probability of new call request type. Therefore, the results demonstrate once again the superiority of the HTGA algorithm.

According to the research results during latest three years, we believe that there is close relationship between the research issues and the original projects. The research results have carried out the project taget we expected. In this field of traffic grooming, we discuss the dymanic traffic grooming under the nonuniform traffic. This problem has not discussed before. Integer linear problem (ILP) methodology is applied to formulate for this problem. Also, we modified a smart method, annealing method, to solve ILP, annealing-based traffic grooming. However, the complexity is very much. We also design another method, heuristic-based traffic grooming. The scheme provides the better performance than the front scheme. For the access-metro ring network, if you want to achieve the highest bandwidth ultilization, you can use the annealing-based traffic grooming scheme. However, if you want to reduce the dropping and also improve the bandwidth ultilization, you should use heuristic-based traffic grooming scheme. Therefor, we provide two schemes to solve the problem of the dymanic traffic grooming under the nonuniform traffic. Also, you can use one of them under the different requirements.

- 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 the first 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 [35] RTS/CTS exchanging messages to quickly detect the movement of mobile nodes. It can improve the performance of traffic transmission during the handover period.

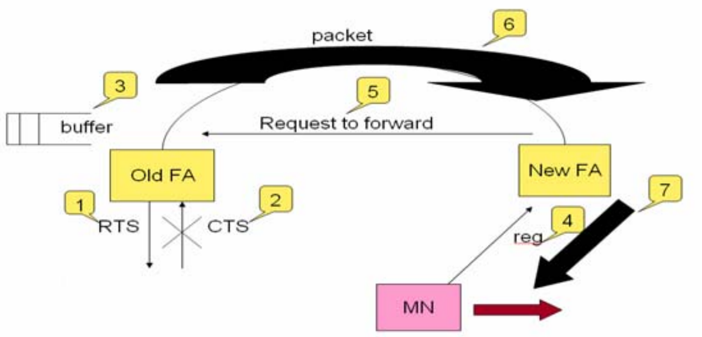


Figure 10. Messages flow of Speedy Handover scheme.

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 10, 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 [36] 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 results demonstrate the effectiveness of the proposed scheme.

In the second year, we design a two-stage authentication scheme to enhance the performance of wireless handover. Since wireless local area networks have become extremely popular in recent years. The wireless services may encounter some problems under different environments, and there are more emerging multimedia streaming applications being developed. When users of these applications move from the coverage area of one AP to the other, the services must be handed over in approximately 150 milliseconds, otherwise the user will experience the jitter. If the handoff time is much larger than 150ms, the quality would be getting worse. This noticeable problem needs to be solved. Many approaches have been proposed from different aspects to reduce the handoff impact. Some focus on layer 2 handoff to reduce the scan, authentication and association latency. Others focus on layer 3 handoff to alleviate the registration and authentication time. The typical solution for reducing handoff time is Hierarchical Mobile IP with Fast handover protocol [37]. Fast

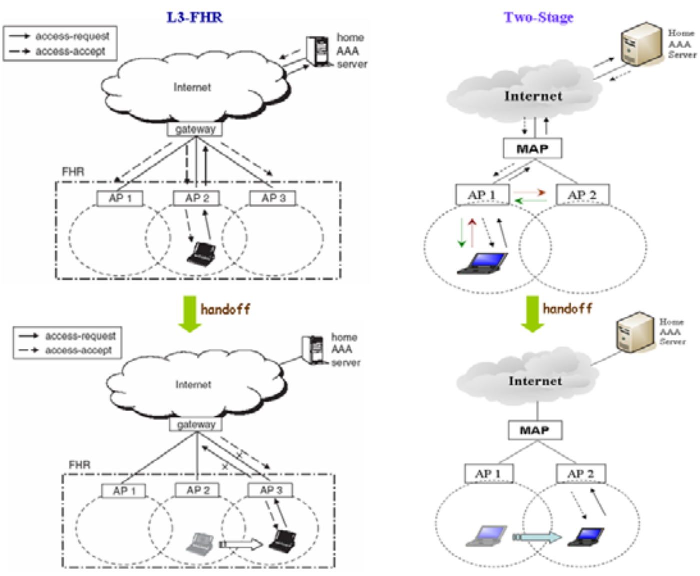


Figure 11. L3-FHR & Two-Stage message flow.

handover protocol [38] needs layer 2 information to early trigger the handoff and it spends approximately 100ms which is much smaller than 3 seconds required by original Mobile IP. This small handoff period allow us to provide a multimedia streaming service during handoff without suffering jitter problem.

Besides handoff, security and authentication issues also become more important nowadays. If we like to enhance the security or to perform authentication, it will add a certain amount of handoff time in addition to the original layer 2 and layer 3 handoff. This is a tradeoff between authentication and QoS, and we need some method to minimize the impact if we add authentication process on it. Fast handover could provide better QoS for roaming devices, based on this advantage, we construct a user authentication signaling that allows the access router to authenticate the mobile node (MN).

To achieve low latency handoff, we make use of pre-registration signaling called fast handover protocol to piggyback user’s information to authenticate with new target AP temporarily for reducing the authentication time during handoff period, it is called “two-stage authentication” as shown in Figure 11. Our two-stage authentication scheme consists of pre-authentication and formal authentication.

A mobile node needs to perform AAA/Mobile IP [39] initial registration when it enters into the new MAP (Mobility Anchor Point) domain. The Home Agent generates keys and authenticates the mobile node when it receives the AAA/Mobile IP registration message. Then, the Home Agent replies the registration to the mobile node through MAP, which then checks the authentication status, signs a certificate CA_{MAP} and adds group key for the mobile node into registration reply message. The mobile node derives the CA_{MAP} after performing the AAA/Mobile IP registration. Then, the mobile node moves from PAR (Previous Access Router) to NAR (New Access Router), it triggers the pre-registration called fast handover signaling to reduce the registration time. We try to make use of this signaling to piggyback some information to pre-authenticate the MN with new target AP temporarily. Also, the MN needs to complete the formal authentication process after handoff in a given limited time. The MN generates a credential to register with new target AR (AP) through fast handover signaling for deriving the temporarily access right in the new domain. After handoff, the mobile node can receive packets quickly by sending this credential to the target AR to present its existence under target AR's coverage. So, the MN doesn't need to wait for completing the authentication process to receive packets. NAR uses CA_{MAP} to identify the mobile node and to register the credential of the mobile node in NAR's authentication table. NAR will return the expiration time of the credential and CA_{NAR} signed by NAR through fast handover signaling to the mobile node. After Layer 2 handoff, the MN can use this credential to pass temporarily authentication and extend its authentication expiration time in NAR's authentication table. CA_{NAR} is for formal authentication usage.

The two-stage authentication scheme can enhance the performance of wireless handover if authentication mechanism is used. Different from the L3-FHR authentication scheme that authentication information is broadcasted by gateway to all L3-FHR [40] ARs(APs) shown in Figure 11, a MN just sends a copy of authentication information to the target ARs (APs) in two-stage authentication scheme. As a result, our proposed scheme can reduce the packet loss rate and authentication time. Our scheme can reduce the original IEEE 802.11 authentication process time because it pre-sends the identity of the MN to target AR(AP). We try to modify this scheme to co-work with IEEE 802.1x to reduce the authentication time and to provide a better authentication mechanism during handoff period in the future research.

In the last year, comparing with the original mobile IP mechanism, speedy handover features a fewer number of packet losses and a shorter handover period. The simulation results demonstrate the effectiveness of the proposed scheme. In this year, we propose a so-called "discrete scan" scheme and relative auxiliary mechanisms that collect a set of candidates for next-APs and eventually select the next AP for a mobile node before a forthcoming handoff. Moreover, various existed mechanisms may select next AP with different properties of the next-AP candidates, such as the nearest AP, the approached AP, the AP of highest available bandwidth, or their combination. Compared with neighbor graphs, discrete scan scheme provides a set of next-AP candidates as a subset of neighboring APs. With the help of proposed auxiliary mechanisms, discrete scan selects an appropriate next AP for a mobile node to handoff to, taking the place of the function of a neighbor graphs with aids of topological information by GPS system proposed in [41].

As a cost, discrete scan scheme contributes an impact to service QoS received by the mobile node in a "pre-handoff" period that is defined as the duration from initiating the discrete scan scheme to the moment when a handoff is initiated. However, taking the advantages of high transmission priority and relative low bit rate for a VoIP connection in EDCA wireless LANs, the degradation may be limited to a degree that the users may tolerate or even may ignore. Estimation on the QoS degradation with analytical approach and simulation results presented in this and next chapter shows that the disruptions caused by discrete scan are bounded to 50 ms based on certain practical assumption.

五、計畫執行管理與自評

本整合型研究計畫「支援下一代無線與FTTx擷取之光纖都會網路技術」為三年期之計畫，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，架設了OPSINET雛形網路來觀察並了解光纖都會型網路的行為。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教授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，最後並針對光纖都會型網路的特性來提供各子計畫在無線與FTTx擷取之技術合作。

在第一年於光纖都會型核心網路，子計畫一除了提出OPSINET都會網狀雛形網路之架構外，另外並設計了一套服務品質訊務控制技術；子計畫二則研究無線網路環境下，編解碼技術之限制以及新技

術研發；子計畫三於被動式光纖網路(PON)之下，根據訊務流量模式，研發預測式排程法；子計畫四探討無限網路漫遊之交遞問題，設計出快速交遞演算法。

計畫的第二年延續著在第一年所獲致之經驗，各子計畫皆有豐碩成果。子計畫一在光纖都會核心網路上，完成了路由與波長分配(RWA^{+})之關鍵技術；子計畫二在無線環境之下，編解碼技術有重大突破；子計畫三在EPON網路上，以新排程法有效提升系統效能；及子計畫四透過兩階段認證機制，在無線漫遊可達到快速交遞之結果。

於計畫的第三年，開始朝向光纖都會環狀網路架構進行設計，子計畫一架構了HOPSMAN環狀網路並提出媒體接取控制(MAC)技術；子計畫二利用平行串接旋積編碼技術，有效提升系統效能；子計畫三提出STGA演算法解決動態訊務彙集的問題；子計畫四則是提出了「不連續掃描」機制來提供偵測交遞對象資訊的功能且排除舊有方法之不實用的缺點。

此三年之研究成果已投稿或發表於國際會議與期刊，並有十篇碩博士生畢業論文產生，論文成果如下：

- 四篇期刊論文
  1. *IEEE Journal of Selected Areas in Communications*：三篇
  2. *IEEE Transaction on Wireless Communications*：一篇
- 四篇會議論文
  1. *International Conference on Informatics, Cybernetics and Systems (ICICS'2003)*：一篇
  2. *IEEE Asia-Pacific Conference on Circuits and Systems (APCCS'2004)*：一篇
  3. *International Conference on Internet Technologies and Applications (ITA 2005)*：一篇
  4. *IEEE/OSA European Conference on Optical Communication (ECOC'2006)*：一篇
- 一篇博士論文
- 九篇碩士論文

然而，目前網路上面的訊務型態呈現多元化的現象，除了傳統資料傳輸之外，語音以及視訊等即時性資料亦須特別考量。加上環狀網路的特性，使得頻寬可進行再利用(bandwidth reuse)。

在接下來的三年期計畫，我們將針對以光纖都會網狀/環狀網路為主幹，而能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)之技術來進行研究。

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] 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.

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

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

[6] R. Ramaswami, and K. Sivarajan, *Optical Networks- A Practical Perspective*, 2nd Edition, Morgan Kaufmann, 2002.

[7] B. Mukherjee, *Optical Communication Networks*, McGraw-Hill, 1997.

[8] D. Banerjee, and B. Mukherjee, “A Practical Approach for Routing and Wavelength Assignment in Large Wavelength-Routed Optical Networks,” *IEEE J. Select. Areas Commun.*, vol. 14, no. 5, Sep. 1996, pp. 903-908.

[9] C. Xiaowen, L. Bo, and I. Chlamtac, “Wavelength Converter Placement under Different RWA Algorithms in Wavelength-Routed All-Optical Networks,” *IEEE Trans. Commun.*, vol. 51, no. 4, April 2003, pp. 607-617.

[10] H. Qin, S. Zhang, and Z. Liu, “Dynamic Routing

and Wavelength Assignment for Limited-Range Wavelength Conversion," *IEEE Commun. Letters*, vol. 7, no. 3, March 2003, pp. 136-138.

[11] A. Mokhtar, and M. Azizoglu, "Adaptive Wavelength Routing in All-Optical Networks," *IEEE/ACM Trans. Networking*, vol. 6, no. 2, April 1998, pp. 197-206.

[12] I.M. White, M. S. Rogge, K. Shrikhande, and L. G. Kazovsky, "A Summary of the HORNET Project: A Next-Generation Metropolitan Area Network," *IEEE Journal on Selected Areas in Communications*, vol. 21, no. 9, Nov. 2003, pp. 1478-1494.

[13] L. Dittmann, et. al., "The European IST Project DAVID: A Viable Approach Toward Optical Packet Switching," *IEEE Journal on Selected Areas in Communications*, vol. 21, no. 7, Sept. 2003, pp. 1026-1040.

[14] A. Carena, et. al., "RingO: An Experimental WDM Optical Packet Network for Metro Applications," *IEEE Journal on Selected Areas in Communications*, vol. 22, no. 8, Oct. 2004, pp. 1561-1571.

[15] M. A. Marsan, et. al., "All-Optical WDM Multi-Rings with Differentiated QoS," *IEEE Comm. Mag.*, vol. 37, no. 2, Feb. 1999, pp. 58-66.

[16] J. Cai, A. Fumagalli, and I. Chlamtac, "The Multitoken Interarrival Time (MTIT) Access Protocol for Supporting Variable Size Packets over WDM Ring Network," *IEEE Journal on Selected Areas in Communications*, vol. 18, no. 10, Oct. 2000, pp. 2094-2104.

[17] C. S. Jelge and J. M. H. Elmirghani, "Photonic Packet WDM Ring Networks Architecture and Performance," *IEEE Comm. Mag.*, vol. 40, no. 11, Nov. 2002, pp. 110-115.

[18] 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.

[19] 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.

[20] 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.

[21] 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.

[22] 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.

[23] 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.

[24] W. C. Y. Lee, "Estimate of channel capacity in Rayleigh fading environment," *IEEE Trans. Veh. Technol.*, vol. 39, no. 3, pp. 187-189, Aug. 1990.

[25]I. C. Abou-Faycal, M. D. Trottand and S. Shamai, "The capacity of discrete-time memoryless Rayleigh-fading channels," *IEEE Trans. Inform. Theory*, vol. 47, no. 4, pp. 1290-1301, May 2001.

[26] 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.

[27] 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.

[28] Chia-Lung Wu, Ya-Ting Cho, Po-Ning Chen and Yunghsiang S. Han, "Iterative MAP algorithm for Gauss-Markov channel, " in preparation for submission.

[29] 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.

[30] 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.

[31] 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.

[32] 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.

[33] 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.

[34] 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.

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

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

[37] Nicolas Montavont et.al., "Handover Management for Mobile Nodes in IPv6 Networks," *IEEE Communications Magazine*, August 2002.

[38] Robert Hsieh, Aruna Seneviratne, Hesham Soliman and Karim El-Malki, "Performance analysis on Hierarchical Mobile IPv6 with Fast-handoff over End-to-End TCP," *Proceedings of GLOBECOM*, Taipei, Taiwan 2002.

[39] Pat R. Calhoun et. al., "Diameter Mobile IPv4 Application," Internet Draft, IETF, draft-ietf-aaa-diameter-mobileip-20.txt, August 2004

[40] S.Pack, Y. Choi, "Fast handoff scheme based on mobility prediction in public wireless LAN systems," *IEE Proc.-Commun.*, Vol. 151, No. 5, October 2004.

[41] C. C. Tseng, L. H. Yen and H.H. Chang "Topology-Aided Cross-Layer Fast Handoff Designs for IEEE 802.11 Mobile IP environment," *IEEE Communications Magazine*, Dec. 2005