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One year ago, in the first CUBIN annual report, I commented that "the telecommunications industry is in a period of significant and sustained growth." Now, a year later, in early 2002, nothing could be further from the truth. Telcos world-wide have cut back on infrastructure upgrades, and the impact on equipment suppliers and subsystem and component vendors has been profound. Reports of cancelled development programs and lay-offs abound, and the telecommunications job market has all but collapsed.

Yet optimism in the long-term future of telecommunications remains high. A few days before writing this, I attended OFC 2002, the premier US-based conference and trade show in Optical Fiber Communications. Despite the industry-wide down-turn OFC 2002 was almost as big as OFC 2001 the previous year. More significantly perhaps, the technical program contained just as many new and exciting developments as in previous years, and the myriad of large and small companies at the trade show exhibited a wide range of new and innovative products.

For reasons beyond their control, some of these companies will not survive the down-turn, but the spirit of innovation and technological advancement continues. There is a widespread and well-founded belief that the telecommunications industry has a very bright future in the medium to long term. The demand for bandwidth will continue to increase, the telcos will work out business plans that can sustain this increase, and the equipment and component manufacturers will enjoy a new period of prosperity. Hopefully the next up-turn will be measured and we will not again experience wild fluctuations in the industry's well-being.

One of the enormous benefits of Australian Research Council funding and the Special Research Centre scheme is that research groups like CUBIN are isolated to an extent from the short-term fluctuations in the fortunes of an industry. Under continued ARC funding, CUBIN has thrived and continued to grow. By weathering the storm, CUBIN is in a position to provide a group of new PhD graduates who will be ready to participate in the recovery of the telecommunications industry.

This report provides an overview of CUBIN activities in 2001. Notable events in 2001 include the establishment of a collaborative agreement with the Optical Internet Research Center at the Information and Communications University in Korea, and the opening of CUBIN's Network Laboratory. Staff numbers have grown to 21, while 28 postgraduate students and 3 visiting students have participated in CUBIN activities.

In June and July, CUBIN researchers undertook a review of the Centre's research program, and established an expanded schedule of activities. The total number of publications by CUBIN researchers has increased from 2001, as did conference presentations. CUBIN staff members have filed six Australian and international patents.

During 2001, CUBIN student Malolm Peh and staff members Stephen Hanly and Jonathan Manton undertook extended visits to overseas laboratories in Asia and the United States. Moshe Zukerman was promoted to Professor, and Subhrakanti Dey to Senior Lecturer. We welcomed a new Senior Lecturer in Jamie Evans, and three new research fellows: Chandranath Athaudage, Keping Long and Brian Krongold, and farewelled Qinghe Yin.

I took a period of study leave from September to December 2001. During that period, Vikram Krishnamurthy undertook the duties of CUBIN Director. I would like to thank Vikram for providing leadership during my absence.

2002 will see the ARC's three-year review of CUBIN, and the setting of plans for CUBIN's future. We look forward to this opportunity to re-evaluate CUBIN's activities and to plan for future growth.

ROD TUCKER
Director

In its second year of operation, CUBIN continued to build upon the success achieved during the year 2000. In 2001, staff and student numbers of CUBIN has grown significantly. Some highlights for the year 2001 are as follows:

CUBIN Network Laboratory and office extension

Acting Vice-Chancellor Professor Sally Walker launched the main CUBIN Laboratory in December 2000. The growing number of postgraduate students and visitors and the need for an experimental laboratory highlighted the need for additional space. An area adjoining the main CUBIN Laboratory in the Electrical and Electronic Engineering building was renovated. This newly renovated area was officially opened on August 31, 2001. It provides desk space for six additional CUBIN researchers, and houses a new CUBIN Network Laboratory (CNL).

The aim of the CNL is to enable advanced network control algorithms to be tested on real devices and products. The CNL currently includes a test-bed system consisting of a highly flexible 100 Mb Ethernet network with a number of switches and PCs running Linux as well as two 802.11 wireless base stations. The CNL has been of great benefit to CUBIN researchers in 2001, and this new resource will be further developed in 2002.

Opening of the Optical Internet Research Centre (OIRC) Overseas Laboratory at CUBIN

The University of Melbourne's Vice-Chancellor Professor Alan Gilbert officially launched a new collaborative venture between The University of Melbourne and the Information and Communications University, Taejon, Korea. Professor Gilbert conducted the opening ceremony on July 31, 2001 with Dr B.Y. Ahn, President of the Information and Communications University. As part of this venture, the Optical Internet Research Centre's Overseas Laboratory in CUBIN was officially opened. The OIRC and CUBIN formally signed a new collaboration agreement between their two home institutions in April 2001, and the new "Overseas Laboratory" will support exchange visits between Melbourne and Taejon researchers.

Whilst opening the new OIRC laboratory, Professor Gilbert described the collaboration agreements importance as underpinning the information economy. "CUBIN is doing world-class research and its reputation is rapidly expanding." He described the OIRC as an outstanding research centre, making important contributions in the world of telecommunications. "Top-class research and graduate studies in this area are critically important to the future of countries like Korea and Australia," he said.

L-R Dr B.Y Ahn, Professor Rod Tucker, Professor Alan Gilbert, Professor Minho Kang

Dr Ziggy Switkowski, CEO of Telstra visits Cubin

Telstra Chief Executive Officer Dr Ziggy Switkowski visited the CUBIN Laboratory on February 5, 2001. Accompanied by Telstra Chief Technology Officer Professor Hugh Bradlow, Dr Switkowski toured the CUBIN Laboratory area. Staff and students from all CUBIN research projects were on hand to present posters detailing their current research directions and to provide insight into the CUBIN research plan. Dr Switkoswki commended CUBIN researchers on their presentations and expressed his hope that CUBIN will continue to provide researchers with the opportunity to develop their work.

L-R Professor Rod Tucker, Dr Ziggy Switkowski, Professor Hugh Bradlow

Ultra-Broadband Information Networks

The field of telecommunications has for many years been centred on telephone services. But the explosive growth in the Internet has changed all this, and it now seems likely that the global telecommunications network will become a greatly enhanced internet offering integrated multimedia services including data and video. Driven by an ever-increasing range of multimedia applications and services, the Internet is growing at more than 100 percent per annum. If this growth rate continues, the total capacity of the network will expand by up to three orders of magnitude within five to ten years and greatly enhanced network infrastructure will be needed.

Based on the above growth projections, ultra-broadband networks of the future will provide customer access bit rates in the hundred megabit (10^8) per second to the gigabit (10^9) per second range. This will be supported by inter-city and intra-city links with data capacities in the multi-terabit (10^{12}) per second regime, and major routing nodes with capacities that may ultimately approach one petabit (10^{15}) per second.

Aims, Objectives and Mission

The Centre for Ultra-Broadband Information Networks (CUBIN) aims to be a national focus for research into future generations of telecommunications networks that will provide virtually limitless amounts of information to any place at any time.

CUBIN seeks to advance fundamental theory and to develop a practical basis for the design, implementation and management of these networks. The Centre will assist Australia to fully capitalize on its international profile in ultra-broadband telecommunications well into the new millennium.

The key objectives of CUBIN are to:

- Undertake research in ultra-broadband information networks, with a focus on advancing theory, and developing analysis and design methodologies for future generations of networks
- Serve as a national focus for interdisciplinary research activities that will underpin the new generation of ultra-broadband information networks and break down barriers between hardware and software developments
- Establish an international presence in ultra-broadband networking research and facilitate active collaboration with leading telecommunications research laboratories in Australia, and with major international laboratories
- Develop close interactions with industry and undertake collaborative research with industry, with the objective of developing technologies and intellectual property with potential for commercialization in Australia
- Provide graduate and postdoctoral training, with the objective of serving the employment needs of the Australian telecommunications industry
- Assist in the development of awareness of the importance of ultra-broadband telecommunications among the broader technical community and the general public.

CUBIN Directorship

In September 2001, the Director of CUBIN, Rod Tucker commenced a period of study leave. Vikram Krishnamurthy undertook the role of Director in Rod Tucker's absence.

Advisory Board

The CUBIN Advisory Board is comprised of distinguished Australian and overseas leaders in telecommunications from academia and the industry sector.

Advisory Board:

Hugh Bradlow	Tesltra (Chair)
Dennis Cooper	AMBRI
Leith Campbell*	Australian Telecommunications CRC
Chris Isaac**	Australian Telecommunications CRC
Tatsuo Izawa	NTT Electronics Corporation
Frank Larkins	The University of Melbourne
David Messerschmitt	University of California, Berkeley
Fergus O'Brien	RMIT University
Tom Rowbotham	St. Paul Venture Capita
Mark Sceats	Australian Photonics CRC
David Skellern	Cisco Systems
Eddy Tirtaatmadja	Lucent Technologies

* *New Member 2001*

** *Retiring Member 2001*

The Advisory Board met in August and December 2001.

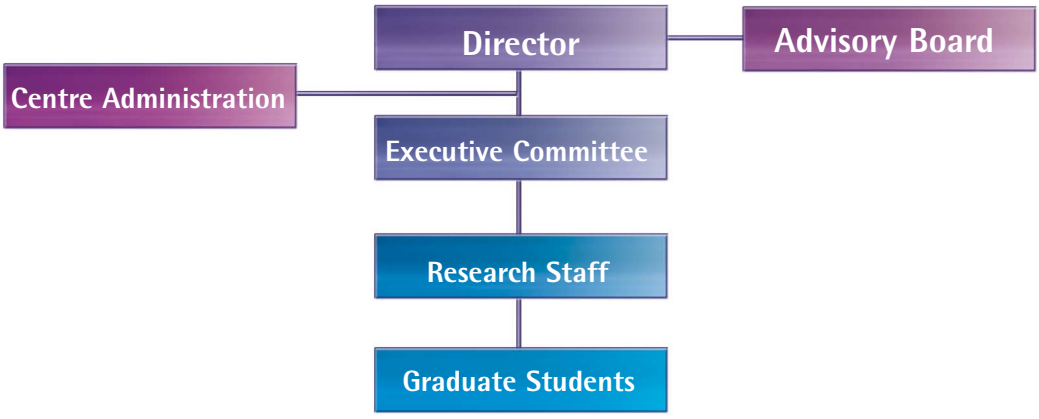
Executive Committee

The CUBIN Executive Committee assumes overall responsibility for research and education programs, finance, performance, staffing and all other matters that are directly related to ensuring the efficient running of the Centre. Executive Committee members are nominated to manage individual programs within the Centre and also serve as coordinators of the Centre's core research projects. The Executive Committee meets on a regular basis. There were twelve formal meetings of the Executive Committee in 2001. Dr Jamie Evans and Dr Subhrakanti Dey joined the CUBIN Executive Committee in October 2001. Their addition brings the number of CUBIN Executive Committee members to seven.

CUBIN Executive Committee:

Subhra Dey*	Director, Network Laboratory
Jamie Evans*	Director, Network Laboratory
Stephen Hanly	Director, Graduate Studies January-September, 2001
Rao Kotagiri	Deputy Director, Director International Programs
Vikram Krishnamurthy	Director September - December, 2001 Director, Workshops and Lectures
Rod Tucker	Director January - August, 2001
Moshe Zukerman	Director, Graduate Studies September-December, 2001

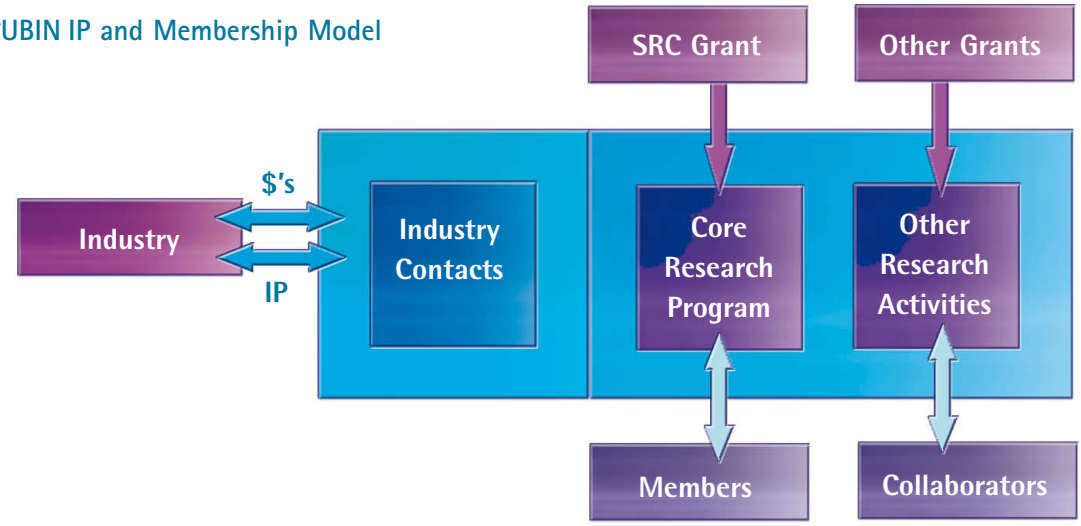
* *New Member 2001*



The diagram below shows how CUBIN's research program is divided into three areas:

- Core research activities
- Other research activities funded by grants
- Industry-funded contract research

CUBIN IP and Membership Model



The core research program is supported by the Special Research Centre grant from the ARC. The "other research" program is funded from a variety of sources, including ARC large grants and SPIRT grants. Intellectual property resulting form this research normally resides with the staff and students who undertake the research work. Intellectual property resulting from industry-funded research is generally subject to conditions set out in the specific contract conditions. CUBIN management take care to ensure that there is no overlap between this intellectual property and intellectual property associated with core research activities and other research activities funded by grants.

There are a number of mechanisms by which industry and other organizations can interact with CUBIN. Industry-funded contracts are one mechanism for interactions with industry. Collaborations with other organizations by researchers working in the core research activities and in other grant-funded activities can take place either informally or through a simple collaboration agreement that gives shared rights to project intellectual property.

Membership of CUBIN

CUBIN offers a membership program to companies and other research organizations. Member companies support the Centre with a variety of contributions including cash funding in the form of donations, involvement of senior-level engineers and researchers, and access to products, equipment and facilities. Member companies have the opportunity to place at least one senior employee in the Centre to interact with Centre Researchers on a regular basis.

Centre member companies and organisations have the opportunity of direct access to, involvement in, and influence on a large multi-disciplinary research effort investigating future telecommunications networks, with a relatively modest investment. Centre member companies and organisations receive pre-prints of all Centre publications, and are invited to the Centre Research Conference, which will be held each year.

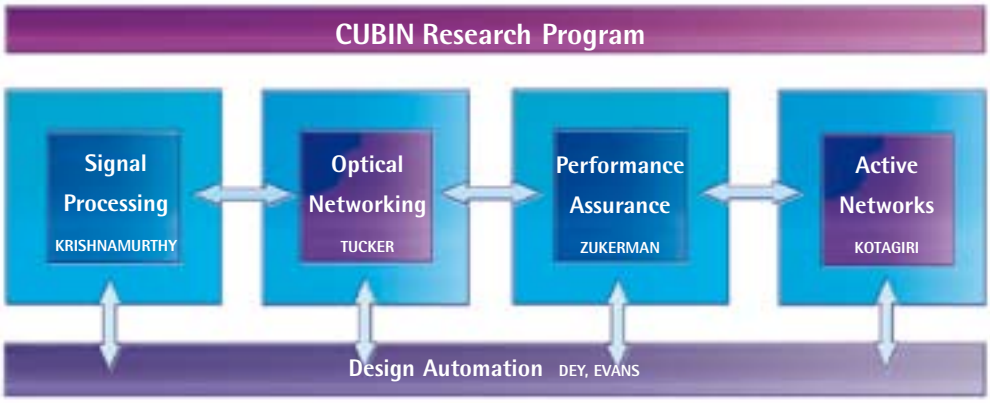
Other benefits of membership include:

- A seat on the Centre Advisory Board
- Free attendance for up to 10 people at all Centre workshops and short courses
- Access to research materials and other documentation via a members-only area in the CUBIN website.

The CUBIN Core Research Program comprises five inter-linked projects:

1. Signal Processing
2. Optical Networking
3. Performance Assurance
4. Active Networks
5. Design Automation

The Design Automation Project was established in 2001, the other four projects built upon the research undertaken during 2000. Set out below are reports on activities in the five core CUBIN research projects.



A. SIGNAL PROCESSING

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Despite significant advances in the transmission rates over core broad-band networks (e.g., optical fibers), wireless access networks are still a key bottleneck in telecommunication networks. Interference due to the time-varying and uncertain nature of wireless channels together with interference caused by other users is the main reason for this bottleneck. It logically follows that statistical signal processing methods for interference management and suppression in wireless networks is of key importance in designing and implementing wireless telecommunication networks of the future.

The broad aims of this project include:

- *developing and analyzing computationally efficient signal processing algorithms for interference suppression in wireless telecommunications networks such as CDMA and OFDM systems.*
- *obtaining a deeper understanding of the interplay between physical layer signal processing and the link and network layers in wireless networks.*

Our research has focused on multi-disciplinary aspects of wireless networks ranging from physical layer algorithms for channel equalization, interference suppression in CDMA wireless networks, the geometry of OFDM systems, to link layer and network layer algorithms for admission control, access control and power control. The research has significant links with the performance assurance project.

SUB-PROJECT 1:

Effect of Physical Layer Signal Processing on Link and Network Layers

The research aim is to develop call admission control, access control and power control algorithms that take into account the physical layer characteristics such as channel fading and receiver structure. In these integrated multimedia networks users transmit at different bit-rates and have different quality-of-service (QoS) requirements, which is usually characterized by a Signal to Interference Ratio (SIR) constraint.

Admission and access control are essential in regulating the quality of service of a wireless CDMA network. They ensure fairness in the utilization of the network and maintain blocking probabilities to a specified tolerance. An integrated systems approach to developing novel admission and access control algorithms needs to consider physical layers characteristics such as the fading channel and the nature of the receiver.

We have developed a constrained Markov decision process formulation for the call admission control problem in CDMA systems with fading channels. Optimal admission control algorithms for minimizing the blocking probability subject to QoS requirements of users in the CDMA network have been developed. The algorithms take into account the physical layer multiuser detection algorithm and uses recent results in large random matrices to characterize the SIR. The Markov decision process formulation has also been used to develop novel access control algorithms that incorporate outage probability constraints and gradient estimation methods.

In interference limited multi-access wireless systems such as CDMA, controlling the transmitted powers of the mobile users is one useful technique for managing interference. Power control not only maintains the required quality of service for each user but also maintains a low radiation level and saves battery life of the mobile handsets. Most existing algorithms proposed in the literature also do not take into account the effect of multipath fading. We have developed a novel optimal power control algorithm is developed for CDMA systems with Markov fading channels. Deterministic iterative optimization algorithms are developed when the channel parameters are exactly known. Imperfections in channel estimates and noise in the feedback channel can be tackled by using sophisticated optimization techniques such as constrained stochastic approximation methods. The results show improved performance for our algorithm compared to existing algorithms that fail to converge in the presence of longer fade durations.

SUB-PROJECT 2:

Adaptive Interference Suppression and Spatial Diversity

In CDMA-based wireless networks, performance measures of interest, such as signal-to-interference ratio, are functions of the signature sequences assigned to each user in the system. This dependence leads to ungainly expressions for network performance indicators and to complex design problems. Recently, a powerful tool has emerged for performance analysis and parameter optimization of CDMA systems. Large system analysis is based on modeling the signature sequences as random quantities and examining the behaviour of the network as the spreading gain and the number of users grow large. In this regime, key

performance measures depend on the eigenvalue distributions of large random matrices. Importantly, in many cases of interest, the limiting spectral distributions have a simple form that only depends on the ratio of the number of users to the spreading gain. The end results are performance measures and design rules that are independent of the signature sequences and solely dependent on the key system parameters. In collaboration with the University of Sydney, we have employed large system analysis in the design of efficient implementations of linear multiuser detectors for CDMA. The end result is an efficient implementation of the decorrelator or LMMSE receiver along with guidelines for optimal parameter selection as a function of system loading and signal-to-noise-ratio.

We also considered the design of LMMSE receivers in rapidly time-varying environments where pilot symbols are used to aid the operation of the channel estimation unit within the multiuser receiver. Inserting pilot symbols into the data streams more frequently will improve the performance of the channel estimation algorithms but at the same time, will chew up valuable time slots that could otherwise be used for transmitting data. By combining powerful large system analysis tools with classical Wiener filtering theory we were able to specify the rate at which pilot symbols should be inserted into the data stream of each user in order to optimize performance.

Researchers are currently developing adaptive multiuser detection algorithms for multirate CDMA systems. These algorithms build on earlier CUBIN work. The algorithms use novel methods for adapting the step size of an adaptive multiuser detector to cope with arrivals and departures of users. We have developed decision theoretic algorithms that decide when to switch between a blind multiuser detector and a decision directed multiuser detector.

We are gaining a deeper understanding of linearly precoded systems (a generalisation of Orthogonal Frequency Division Multiplexing and Zero Padding systems). At the core of this work is the discovery of a natural convex geometry for linearly precoded systems. Using this convex geometry, it has been proved that the role of linear precoders is "orthogonal" to the role of more traditional error correcting codes; linear precoders reduce the effects of fading but offer no protection against Gaussian noise. Moreover, stochastic optimisation routines were developed for designing optimal linear precoders; previously, no method was available for designing optimal precoders for coding over random channels. Related research includes the development of the Fisher Information Decision Directed Quantisation method that improves considerably the performance of a communication system without a significant increase in computational complexity. Blind source separation issues were also addressed.

Future Plans (Signal Processing)

- develop efficient implementations of linear multiuser receivers for rapidly time-varying environments
- develop design guidelines and algorithms for adaptive selection of pilot insertion rate in non-stationary fading environments
- investigate optimal power and rate control for integrated voice and data networks in 3G wireless systems in the presence of multipath fading
- devise fast suboptimal algorithms for admission and access control in wireless networks.

B. OPTICAL NETWORKING

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The emergence of today's Internet and its applications are causing a revolution in telecommunications. In order to meet the tremendous growth in bandwidth requirements caused by the explosive growth in the Internet traffic, network operators are currently deploying WDM-based optical transport networks in the WANs, MANs and ultimately in access networks. In addition, it has become clear that the common traffic convergence layer in communication networks will be IP because practically all end-user communication applications today make use of the TCP/IP protocol. Combining these two trends, IP over WDM is now emerging as a winning combination in new network architectures. However, a number of interesting problems and challenges arise in the domain of wavelength routed networks, including network architectures, lightpath routing coupled with a need for tighter interworking with IP routing and resource management protocols, intelligent control plane and network management capabilities, and others.

The broad aims of this project are to:

- *investigate cost-effective, scalable, flexible and survivable network architectures that capitalise on future generations of transmission and switching technologies*
- *develop models of ultra-broadband access networks and trunk networks based on projected traffic growth*
- *evaluate the impact of emerging technologies on network architecture design*
- *develop routing and wavelength assignment algorithms for optical networks*
- *investigate the potential for packet switching and burst switching in optical networks*
- *investigate protection/restoration coordination schemes between the IP layer and optical layer.*

SUB-PROJECT 1:
Network architectures and modeling

In this sub-project we are developing a model of an Australian national network that can carry the projected traffic demands of the next decade using the new generation of optical transport technology. At present, we are concentrating on the architecture of metropolitan and national trunk networks, rather than access network design. In order to formulate the problem, we have defined three future scenarios for customer demand in terms of 10 Mb/s, 100 Mb/s and 1 Gb/s connections to the home. In addition, we have quantified the capacity of the WDM equipment that we expect to be available, e.g., up to 40 Gb/s per wavelength, up to 250 wavelengths per fibre, and optical cross-connects with up to 1000 ports.

The key challenges in this design problem are how to use the capacity of dense wavelength-division multiplexing (DWDM) technology to reduce the load on routers at the IP layer, while accommodating the constraints imposed by DWDM components. For example, a key constraint in this kind of network is the number of ports in an optical cross-connect (OXC). Although we can reduce the load on routers by using dedicated wavelengths through the network, this increases the number of wavelengths passing through

each OXC. If a ring topology is used to connect the OXCs, we have shown that an all-optical trunk network for Australia would not be able to cope beyond the 10 Mb/s scenario due to the OXC port constraint. Although a fully meshed topology can cope with all scenarios, it would be prohibitively expensive in terms of fibre costs.

We have developed a design tool to analyse several partial mesh and hierarchical topologies, and demonstrated that a hierarchical topology provides the most scalable solution for satisfying our design constraints. Our next step is to extend our design tool to optimise the design based on the relative costs of different network components.

We have proposed protection and restoration strategies to achieve survivability in multi-layer networks such as WDM-based SDH networks or IP-over-WDM networks. Moreover, we have proposed a model for multi-layer networks survivability based on a resource sharing pool, which avoids redundant protection in lower layer.

SUB-PROJECT 2:

Dynamic routing algorithms

The second major activity is how to design the virtual topology of lightpaths through a given physical network topology. A lightpath is an optical channel that connects two routers in the network. A lightpath can traverse several physical links and OXCs, thus reducing the amount of routing that is performed at the IP layer. Important issues in the design of virtual topologies is how to route lightpaths through the network, and how to assign wavelengths each lightpath so that it uses the same wavelength on each physical link.

There is a trade-off between routing traffic at the IP layer, and creating dedicated lightpaths at the optical layer. An important problem is how to optimise this trade-off in order to maximise the traffic carried or the spare capacity of the network. We have modelled this as a mixed integer linear programming problem, which includes constraints for wavelength assignment and router throughput. We are currently investigating how the complexity of this model scales as the size of the physical network increases.

An alternative approach is to use heuristic algorithms for routing and wavelength assignment. We have investigated two heuristic algorithms: fixed routing with first-fit wavelength assignment, and adaptive unconstrained routing. We have tested these algorithms on two trunk network topologies, and examined the effect of using wavelength converters and multiple fibres. A key finding of this work is a power-law relationship between the blocking probability and the offered traffic to the network. This suggests that it may be possible to build an analytical model for predicting network capacity at a given blocking probability.

SUB-PROJECT 3:

Optical burst switching

Optical Burst Switching (OBS) is a step towards the ultimate goal of optical packet-switching in next-generation IP-over-WDM optical transport networks. In OBS, data packets are aggregated into much larger bursts before transmission through the network. This allows amortisation of the switching overhead across many packets. The burst is preceded in time by a control packet, which requests resource allocation at each switch. When the control packet arrives at a core cross-connect (or switch), capacity is reserved in the cross-connect for the burst. If capacity can be reserved, the burst can then pass through the cross-connect. The benefit of OBS over circuit switching is that there is no need to dedicate a wavelength for each end-to-end connection. OBS is more viable than optical packet switching because the burst data does not need to be buffered or processed at the switch, so that the strengths of optical switching technologies

can be leveraged effectively and the problem of buffering in the optical domain (for which technology does not yet exist) is circumvented.

During 2001, we have developed a simulation framework for performance evaluation and burst size optimization in OBS networks, using the OPNET Modeler™ simulation package. The OBS simulation models which we have developed enable us to determine performance metrics such as burst blocking/dropping probability, network utilisation and end-to-end latency, and form a basis for future development of novel wavelength assignment algorithms and burst assembly algorithms for increasing performance and realising quality of service provisioning IP-over-WDM networks. We have analyzed the utilization of system capacity in OBS systems and have investigated a number of approaches to handling multiple services with different QoS requirements. Our studies have shown a significant potential for performance improvement in throughput and aggregation delay (the delay associated with burst aggregation at the source) for deterministic (synchronized) traffic over statistical traffic. We believe that OBS can achieve improved utilization and aggregation delay if the sources are properly synchronized.

We have proposed a method to strictly prioritise switching access in "just enough time" (JET) optical burst switching networks, in which capacity is reserved only for as much time as required to accommodate the burst data (compared with other schemes which may allocate capacity from the time the control packet arrives at the switch rather than when the burst data arrives at the switch). A queuing model has been developed by which the blocking probability for each traffic class can be analytically evaluated.

SUB-PROJECT 4:

Pilot tone diagnostics and monitoring in optical cross-connects

In optical networks, optical channels are routed at optical nodes using optical cross-connects (OXC's). To ensure that each signal passes through the OXC to its correct destination, it will be necessary to monitor operation of the OXC. We are investigating the use of low frequency signals (pilot tones) for monitoring optical signals or channels and for tracing these signals through the OXC. Pilot tones are assigned to each wavelength on each input fibre to the OXC, and these signals are detected at the output ports of the OXC. In addition to providing a monitor of OXC routing, pilot tones can be used for power and dispersion monitoring of channels.

Our work is currently focusing on the generation and deletion of pilot tones using optical modulators and by gain modulation of the optical amplifiers. Before the multiplexer a small portion of signal is tapped for detection of the pilot tones, which is used to identify each channel. At the output port of the OXC, pilot tones are removed actively using optical modulators or by gain saturation of the optical amplifiers.

Future Plans (Optical Networking)

- develop an optimisation algorithm for optical network design
- investigate optimum placement of regenerators and IP routers in optical networks
- optimize IP routing with optical wavelength assignment
- investigate pilot tone techniques for cross-connect monitoring
- develop QoS management techniques for optical burst switching using intelligent scheduling schemes
- develop schemes that support synchronization of sources in OBS systems
- extend the resource sharing pool model to IP over WDM networks
- explore mechanisms for OBS support of IP DiffServ QoS architectures
- evaluate OBS burst assembly schemes using self-similar traffic and Possion traffic.

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Despite the expected dramatic increase in capacity, due to increase in demand, the future Internet will likely require means for network design, traffic engineering and management techniques for the provisioning of end-to-end quality of service at minimal cost. The Performance Assurance project provides such means. We are investigating the effect of aggregating traffic from access networks (wireline and wireless) on the core network, how best to design and dimension the network and how best to employ flow control, and other network controls, in the presence of bottlenecks.

The broad aims of this project are to:

- *develop criteria for topology design*
- *develop models for wireline and wireless network dimensioning*
- *investigate topology optimisation techniques*
- *develop efficient techniques for traffic management, Connection Admission Control (CAC), routing, scheduling and congestion control*
- *develop means for modelling and performance evaluation of traffic management techniques.*

SUB-PROJECT 1:

Network Design and Dimensioning

In this sub-project we develop models and guidelines for topology design and dimensioning of wireline and wireless modern telecommunications networks.

Considering an IP over WDM core network, with label switching at the network layer, and wavelength switching at the physical layer, we have assumed a wholesaler-retailer model where the retailer aims to optimise its network reliability. A new criterion for network reliability was developed taking into consideration different penalties (consequences) for different failure scenarios.

In collaboration with the Optical Networking project team, we have made a fundamental contribution towards the development of guidelines for design and dimensioning of Optical Burst Switching (OBS) networks. In particular, we have developed a framework for OBS network design which provides conditions for OBS feasibility and the relationship between burst size, or equivalently, burst assembly delay and throughput, taking into consideration control packet processing and the number of available wavelengths per fibre. Furthermore, we have analysed and study the performance of various design options considering queueing of control packets and synchronization of traffic sources.

During 2001 we have developed performance evaluation and dimensioning of telecommunication systems taking into consideration TCP as well as link layer flow control effects. We have developed a fixed-point model of TCP flow control over a wireless link that accounts for wireless losses, and provides a formula for throughput. We are still in the process of validating this model.

In the area of wireless network dimensioning, in particular, for a CDMA network, we have developed a simple formula to obtain the required base station density to support a given density of traffic, and given QoS requirements. Using a new approach we were able to obtain accurate analytical results for IEEE 802.11 networks. This analysis can be used for a dimensioning tool of such networks.

Normally, topology optimisations of real networks are not scalable, namely, they can be shown to be NP Hard problems. In some specific cases polynomial time solutions are available but they are rare. Therefore, heuristics are often used to obtain sub-optimal solutions. During 2001, we have not achieved novel results in this area. Nevertheless, there where several results that relate to network optimisation problems, in particular, we have investigated and obtained results on underlying theoretical properties of minimum cost networks under various constraint structures.

SUB-PROJECT 2:

Traffic Management

In this sub-project, we develop algorithms and techniques for a range of traffic engineering and management functions for modern wireless and wireline telecommunications networks. These functions include: Connection Admission Control (CAC), routing, scheduling and congestion control.

As a follow-up on our Internet flow control algorithm theoretical framework developed in 2000, which led to the invention of a new Active Queue Management (AQM) scheme called Random Exponential Marking (REM), we focused in 2001 on practical implementation. This led to a new rate based AQM invention called Green. Green has been implemented under LINUX, and has shown to outperform existing AQM implementation. A provisional patent application for GREEN has been filed. We have also extended the applicability of GREEN to provide specified QoS for different service classes, under DiffServ architecture.

Transmitting variable-bit-rate real-time data on the uplink of a polled wireless local area network (WLAN) requires careful scheduling to achieve satisfactory quality of service and capacity. This is a "blind" scheduling problem, since the number and arrival times of packets at each remote station are not known by the scheduler. This is of particular importance when the sources produce unequal amounts of data, or are bursty; the scheduler must trade off polling high rate stations against wasting resources by polling stations which may have no data.

Work in CUBIN has addressed this issue by using the limited feedback allowed by the main WLAN standard, IEEE 802.11, to distinguish between stations, which are known to have more data to transmit and those that may not. This forms the basis for the least-recently-used round robin (LRU-RR) scheduling algorithm. Most importantly, LRU-RR can form the basis for a wireless version of the Dual Queue scheduling discipline, which reduces the impact of short periods of congestion. We have developed an end-to-end flow control protocol for wireless links that only relies on measurements made by the sending and receiving nodes. The protocol simultaneously maximises the utilisation of the precious wireless links whilst minimising transmission latency and buffering requirements. Further work, currently in progress, is generalizing the algorithm for a multi-access scenario where several flows interact at the wireless bottleneck link. Practical implementations, which are compatible with existing Internet protocols, are being developed.

We have developed a model for connection admission control (CAC) for CDMA. In particular we have considered a CDMA system consisting of users transmitting to an antenna array with a multi-user receiver, and obtain the limiting signal-to-interference (SIR) performance in a large system using random spreading sequences. This result is then used to characterize how many users at each SIR level can be accommodated in the network. In the case, when the fading distributions to the antennas are identical, we have discovered the phenomenon of "resource pooling": the multi-antenna system behaves like a system with only one antenna but with the processing gain the product of the processing gain of the original system and the number of antennas, and the received power of each user the sum of the received powers at the individual antennas.

Aiming to minimize the use of network resources for multicast communications, we have developed a new method for multicast routing in a dynamically changing environment based on ant colony optimisation technique. The advantage of our method over existing method is that it uses virtual pheromone, which allows rapid changes in the topology of the underlying multicast tree. We plan to extend the work to apply our results to support QoS requirements such as delay and jitter.

Future Plans (Performance Assurance)

- develop performance models for wireline and wireless network
- investigate topology optimisation for future core networks
- develop efficient techniques for traffic engineering and management.

D. ACTIVE NETWORKS

STAFF: Rao Kotagiri (Project Coordinator)
Stephen Hanly
Chris Leckie
Marimuthu Palaniswami
Moshe Zukerman

STUDENTS:
Laurence Park (PhD)
Tao Peng (Masters)
David Prior (PhD)

COLLABORATORS:

Steven Low	*(Caltech, USA)*
Nick Maxemchuk	*(AT&T Laboratories)*
Rob Pattie	*(Telstra Research Laboratories)*
Iradj Ouveysi	*(Telstra Research Laboratories)*
Farzad Safaei	*(University of Wollongong)*

Active or programmable networking is a new concept, in which packets not only carry data but also information for network control. The control information can be as simple as Quality of Service (QoS) parameters for a flow control algorithm or as complex as a small program to be executed at a router or switch. This will enable the network to be restructured very quickly to allow new services to be provided simply and flexibly. It is a concept that could be of enormous importance in networks of the future. By linking software and hardware aspects of active networking, the Centre will be well placed to play a role in this new and important area.

The broad aims of this project are project are to:

- *develop distributed schemes to improve network performance by taking advantage of the functions provided by active networking*
- *determine the computational requirements of active routers based on the type of packet processing needed for performance management*
- *investigate new algorithms for improving the efficiency of access to distributed databases.*

SUB-PROJECT 1:

Active Networks for QoS

The aim of this sub-project is to study fundamental issues related to active networks and their influence on Quality of Service.

We are studying programmable routers, and how these can be used to provide enhanced QoS in networks. The ability to process packets more intelligently assumes that there is adequate processing capacity in the routers. This is more likely in access routers, where the level of traffic is low, than in backbone routers. Consequently, we are concentrating on using active networks to improve QoS in limited bandwidth access networks. An important example of such an environment is streaming delay sensitive applications over bursty, wireless channels. In this context, active networking can be used to feed back information about congestion, so that the source can selectively drop packets or adapt its coding scheme.

SUB-PROJECT 2:

Active Networks for Distributed Network Monitoring

The aim of this sub-project is to use active networks in the monitoring of network performance.

An important issue in network management is how to detect and diagnose network performance problems. By using active and programmable networking, each router can selectively activate monitoring in response to a problem, and cooperate with neighbouring routers to isolate the cause of the problem. We have focused on two applications where active monitoring can be used: network intrusion detection, and the diagnosis of congestion problems.

The aim of network intrusion detection is to monitor network traffic for signs of malicious activity. A common form of network intrusion is network scanning. Network scans are widely used by attackers as a way of mapping the structure and configuration of a target network. The main difficulty in detecting network scans is that attackers have many ways of hiding their intentions, for example, by randomising the order of their scan or spreading it over a long time

period. We have developed a real-time algorithm for detecting network scans that combines an efficient way to index accesses with a probabilistic model to detect the likely scan sources. In contrast to previous approaches, our model takes into consideration both the number of hosts or ports accessed by a source, as well as how unusual these accesses are. We can then rank the likelihood of suspicious sources being normal or an attacker. Our algorithm has been able to detect highly randomised scans in real-time from packet traces of a large network with over 2,000 hosts.

A major challenge for managing IP networks is tracing the source of packet flows that cause congestion. For example, denial-of-service attacks can severely disrupt the Internet, but can be extremely difficult to trace due to the attacker's ability to fake the source address in IP packets. A promising approach to solving the IP traceback problem is Probabilistic Packet Marking (PPM). In this approach, routers mark the packets that pass through them so that the destination can reconstruct the path taken by these packets. We developed several techniques to improve the performance of PPM by adjusting the marking probability used by each router, so that the destination receives packets marked by each router with equal probability. By implementing this scheme, we have reduced the number of packets needed to reconstruct the attack path by over 50 percent in comparison to traditional PPM techniques on simulated denial-of-service attacks.

The research challenge for active networks in this context is to define the functionality and intelligence that needs to be available in routers, e.g., detecting abnormal traffic patterns, and correlating patterns of behaviour between routers. Currently, we are developing suitable distributed algorithms that can be used by active networks for these types of monitoring applications.

Sub-Project 3: Replication and Caching Strategies

The aim of this sub-project is to use active networks to minimize network and server latency using replication and caching techniques.

A common method for improving access to content on the Internet is to replicate popular content on multiple servers. By replicating content we can reduce both server and network delay. We need to ensure that the user load is evenly distributed between the replicated servers in order to maximise the throughput of our set of servers. To address this problem, we are investigating techniques for load balancing between replicated servers, where the servers are geographically distributed over a wide-area network.

Our aim is to route queries so that servers with large network and server delays receive fewer queries than servers with small delays. However, we want to avoid keeping complex state information at each router about network and server performance in order to make this routing decision. We have developed a load balancing algorithm that runs in the servers, rather than in the routers. This keeps the complexity in the servers rather than the network, and keeps the routers simple. In addition, the servers can balance their load based on measurements of both server and network delays. This helps to move traffic away from congested sub-networks and overloaded servers. Simulations have demonstrated that our load balancing algorithm can significantly reduce average query delay across the network in comparison to the default strategy of using the nearest server.

SUB-PROJECT 4:

Improving the Efficiency of Web Search Engines

The aim of this sub-project is to improve the efficiency of search engines on the Web.

An ongoing challenge in large information networks is how to find relevant documents when searching for information. The problem with today's Web search engines is that they rely on word frequencies, and ignore any structure or word flow throughout the documents. We have developed a search technique, called Fourier Domain Scoring (FDS) to overcome this problem. The FDS technique records not only the number of times each word appears in a document but also its position throughout the document. Once this word signal is obtained, the Fourier transform is performed. This allows us to find documents that have matched phase keywords (implying that the words appear near each other). Experiments have been performed, and show that FDS gives superior results when compared to the standard cosine vector space method. We are currently examining the effect of different transforms on the word signals. Different transforms produce different information and hence may produce better results.

Future Plans (Active Networks)

- develop distributed algorithms for detecting, tracing and controlling network congestion
- develop distributed algorithms for intrusion detection between a set of cooperating routers
- investigate the use of reinforcement learning for load balancing in distributed servers.

E. DESIGN AUTOMATION

STAFF: Subhrakanti Dey (Project coordinator)

Jamie Evans (Project coordinator)

All CUBIN Research Staff are involved in this project.

STUDENTS:

All CUBIN Students contribute to this project.

A common theme of research in the Centre is modelling, analysis and synthesis. The ultimate goal of all the projects is to provide high quality contributions to the fundamental theory and practice of design, implementation and management of ultra-broadband networks. Indeed, much of the intellectual property developed in the Centre will be in the form of algorithms and design tools. The Design Automation project is an overarching activity aimed at facilitating the development of tools that can assist in the design and analysis of ultra-broadband networks.

At present, the aims of this project are:

- to establish a framework for integration of the various algorithms, models and software modules developed in the centre
- to use this framework to facilitate the development of computer-aided design methodologies
- to develop hardware test-beds that can be used to emulate real networks for design and performance testing of new algorithms developed in the Centre.

Based on the modeling, analysis and design tools developed in the four other core projects in the Centre, the Design Automation project is ready to embark upon a new stage of development in 2002. In view of this, planning is in progress to first build a repository of all the software developed in the Centre, e.g., a web page to directories for each contribution, containing code, executable files, sample test data and results, necessary documentation etc. Examples of such contributions include: a queuing network simulator package, a wireless channel simulator, a Java network visualization toolkit etc. A later stage of this

project will see the development of some standard libraries that will efficiently link the constituent modules together.

On the hardware side, the CUBIN Network Laboratory was established in 2001 to complement the theoretical work being undertaken in the Centre. The aim of the Laboratory is to enable advanced network control algorithms to be tested on real devices and products. Currently, the Laboratory contains a highly flexible 100Mb Ethernet network with an number of switches and PCs running Linux, as well as two 802.11 wireless base stations. The Laboratory has already facilitated the development of new active queue management and scheduling algorithms for the next generation of routers. Future work will include medium access control MAC for wireless, a test bed for internet differentiated services, DiffServ, and IP over wireless emulation.

Back row from left:
Ananda Kusama, Duong Pham, Jolyon White, Chris Leckie, Marija Bohocki, Stephen Hanly, Lachlan Andrew, Johannes Whittenby, Nam Nguyen, Vikram Krishnamurthy, Hassan Beloch, Jun Guo, Keping Long.

Middle row from left (seated)
Brian Krongold, Katerine Martin, Subhrakanti Dey, Zvi Rosberg, Meipeng Feng, Felisa Vazquez-Abad

Front row from left:
Tao Peng, Irina Baltcheva, Jia Weng, Chandra Athaudage, Laurence Park

Future Plans (Design Automation):

The very nature of this project has seen an inevitable incubation period during the year 2001 however the later part of 2001 has seen an intensive planning phase for the Design Automation project. Clearly, an exciting and promising future awaits this project in 2002 when

- the CUBIN Software Repository will be built to house software modules and packages developed by all other projects in the Centre
- with an eye toward higher software integration, planning will begin for the development of a common standard on data structures and file exchange, and a standard on representation of various properties of the physical layer as well as representation of traffic
- the CUBIN Network Laboratory will be expanded to allow testing of a broad range of applications for which algorithms have been developed in the Centre.

Other Research Activities

CUBIN Staff and students are involved in a number of other research activities that are outside the core research program. A selection of these non-core projects is listed below.

- Traffic Modelling and Link Dimensioning
- Network Management
- Analysis and Synthesis of MAC Protocols
- The Unbounded Knapsack Problem
- Steiner Networks: Theory and Applications
- Nortel Networks: TCP over wireless links
- Sequential paging in GSM Mobile Systems

In the year 2001, there were twenty-eight graduate students enrolled in CUBIN. Nineteen students were enrolled as PhD candidates, and nine were completing Masters theses. Five students submitted theses for examination in 2001. CUBIN provided studentships for six CUBIN students during the course of 2001.

CUBIN GRADUATE STUDENTS	THESIS TITLE	SUPERVISOR(S)	DEGREE UNDERTAKEN
Hassan Ali Baloch	Blind Channel Estimation and Equalization in Mobile and Wireless Communication Systems	Yingbo Hua and Arnaud Doucet	PhD
Azzam Barakat	Resource allocation in third generation mobile communication system	Stephen Hanly and David Everitt	PhD
Shijie Bi	Network Level multiuser detection	Vikram Krishnamurthy	PhD
Marija Bohocki	Optical Monoitoring in WDM	Rod Tucker and Thas Nirmalathas	Masters
Thanh Bui	Quality of Service improvement in mobile CDMA systems	Vikram Krishnamurthy	Masters
Fraser Cameron	A teletraffic analysis of development in multimedia wireless networks	Moshe Zukerman	PhD
Bao Ling Chan	Mobile Communications	Stephen Hanly and Subhrakanti Dey	Masters
Sead Amir Hassan Djalalian-Assl	Investigation on the integration of the TMN compliant management system and COBRA Adaptive/Mobile agent in Network management	Moshe Zukerman and Leon Sterling	PhD
Chuan Heng Foh	Analysis & synthesis of medium access protocols	Moshe Zukerman	PhD
Xin Huang	Traffic management and overload control for multimedia mobile and wireless networks	Moshe Zukerman	PhD
Ricky Hung	Internet Traffic Management (ITM)	Moshe Zukerman	PhD
Tony Jan	Admission Control in Internet	Vikram Krishnamurthy	Masters
Ananda Kusuma	Radio Resource Allocation for Multihop Cellular Networks	Lachlan Andrew and Stephen Hanly	Masters
Chia Min Lee	Connection admission control for wireless broadband communications networks	Moshe Zukerman	PhD
John Leung	Flow Control of IP Traffic over a wireless list	Stephen Hanly	PhD
Rami Mukhtar	Efficient transport over heterogeneous IP networks	Stephen Hanly	PhD
Timothy Neame	Multimedia traffic characterisation and modelling	Moshe Zukerman	PhD
Laurence Park	Analysis and extraction of useful information across networks of web databases	Marimuthu Palaniswami and Rao Kotagiri	PhD
Rajendran Parthiban	Control & optimisation of telecommunication networks	Rod Tucker and Chris Leckie	Masters
Malcolm Peh	Resource management in cellular wireless networks	Stephen Hanly	PhD
Tao Peng	Defending against Denial of Service Attacks and other high-bandwidth traffic	Chris Leckie and Rao Kotagiri	Masters
Duong Pham	Automated Design of Wireless Communications Systems	Jonathan Manton	PhD
David Prior	Application of Active Networks to Communications	Stephen Hanly	Masters
Ravi Ranasinghe	Wireless LANs	Lachlan Andrew and David Everitt	PhD
Taka Sakurai	Performance evaluation of communication networks with heavy-tailed phenomena	Stephen Hanly	PhD
Jolyon White	Optical Burst Switching	Rod Tucker and Keping Longr	Masters
Bartek Wydrowski	Internet Congestion Control	Moshe Zukerman	PhD
Oxana Yarrovi	Traffic management optimisation for an ATM VP core network	Moshe Zukerman and Marcus Brazil	PhD

Five CUBIN Graduate Students have submitted theses for examination in 2001. Three students have submitted a PhD Thesis for consideration, whilst two students have submitted a Masters Thesis. No graduations occurred in 2001.

CUBIN GRADUATE STUDENTS	THESIS TITLE	SUPERVISOR(S)	DEGREE UNDERTAKEN
Azzam Barakat	Resource allocation in third generation mobile communication system	Stephen Hanly and David Everitt	PhD
Thanh Bui	Quality of Service improvement in mobile CDMA systems	Vikram Krishnamurthy	Masters
Fraser Cameron	A teletraffic analysis of development in multimedia wireless networks	Moshe Zukerman	PhD
David Prior	Application of Active Networks to Communications	Stephen Hanly	Masters
Ravi Ranasinghe	Wireless LANs	Lachlan Andrew and David Everitt	PhD

SHORT COURSE AND WORKSHOP

Jointly sponsored by CUBIN, Australian Photonics CRC Photonics Research Laboratory and IEEE LEOS Victorian Chapter, this two-day program highlighting Optical Networking brought together a number of national and international researchers from the tertiary and industry sectors. The program consisted of a Short Course and Workshop.

Short Course

The Optical Networking Short Course, held on November 1 2001, was aimed to provide researchers and engineers with a good understanding of developments in both photonics and traffic engineering. A panel of experts from photonics and traffic engineering backgrounds, working in both education and industry, including Professor Farzad Safaei (University of Wollongong), Dr Thas Nirmalathas (Australian Photonics CRC Photonics Research Laboratory), Dr Jennifer Yates (AT&T Laboratories), Dr Kerry Hinton (Telstra Research Laboratories), Dr Tom Chae (Australian Photonics CRC Photonics Research Laboratory) and Professor Moshe Zukerman (CUBIN) examined concepts related to WDM Systems and Network Management.

The Short Course attracted over 40 people and was structured in a tutorial style that encouraged interaction between the speakers and the audience. The Short Course itself was divided into six tutorial sessions, followed by a panel led discussion, which allowed the opportunity for discussion and questions to occur concurrently with the discussion of the topic.

The Optical Networking Workshop was held the following day, November 2 2001, and was designed to bring Australian researchers together to enhance the interaction and collaboration in optical networking research. The scope of the workshop included:

- photonic and electronic component technologies
- optical and electrical network subsystems and systems
- optical network architectures
- optical network management
- modelling and optimisation of optical networks

The three plenary speakers invited to the Workshop were Dr Frank Ruhl (Telstra Research Laboratories), Dr Jennifer Yates (AT&T Laboratories) and Dr Stewart Day (Agilent Technologies). Other speakers at the Workshop included representatives of international and national education institutions and local industry such as The University of Melbourne, Osaka University, Monash University, VPI Systems and JDS Uniphase. More than 50 researchers and engineers were in attendance at this full day event representing institutions such as Ericsson, The University of Melbourne, Telstra Research Laboratories, AT&T Laboratories, Osaka University, Monash University, VPI Systems, RMIT University, Agilent Technologies, Redfern Integrated Optics and the University of Sydney.

PLENARY SESSION

CHAIR: Professor Rod Tucker

SPEAKERS:

"Toward All-Optical Networks"	Dr Frank Ruhl, Telstra Research Laboratories
"Building Reliable Transport Networks"	Dr Jennifer Yates, AT&T Laboratories
"Intelligent Optical Networks and GMPLS"	Dr Stewart Day, Agilent Technologies

Optical Networking Workshop: Plenary speaker, Dr Frank Ruhl.

SESSION 1 Chair Professor Moshe Zukerman

"Design Method of Logical Topologies in WDM Network with Quality of Protection"
J. Katou, S. Arakawa and M. Murata, OSAKA UNIVERSITY, JAPAN

"Modelling Future Broadband National Networks"
R. Parthiban, R. Tucker and C. Leckie, CUBIN, THE UNIVERSITY OF MELBOURNE.

"An Overview of DWDM 40 Gbps Transmission Technology and its Impacts on Optical Networking"
L. N. Binh, MONASH UNIVERSITY.

"Ultra-long Terrestrial 40 Gb/s Based WDM Transmission (Over 2200km) with 100 km Amplifier Spacing"
Y.J. Wen and A. Nirmalathas, Australian Photonics CRC, THE UNIVERSITY OF MELBOURNE.

"Impact of incoherent crosstalk from narrow linewidth sources on forward error correction at high bit rates"
S. D. Dods, (Australian Photonics CRC, THE UNIVERSITY OF MELBOURNE) and A.J. Lowery (VPI SYSTEMS)

"A Reliability Measure for Survivable WDM Network"
M. Feng, H. L. Vu and M. Zukerman, CUBIN, THE UNIVERSITY OF MELBOURNE

Optical Networking Short Course: Dr Jennifer Yates speaks on "Light Path Concept in WDM Networks.'

SESSION 2 Chair Dr Sarah Dods

"A Protected Optical Virtual Ring Network Over A Star-Configured Optical Cable Plant"
C.J. Chae and R. S. Tucker, Australian Photonics CRC, THE UNIVERISTY OF MELBOURNE.

"Collision Avoidance in Optical Local Area Networks: Characterisation of a Baseband Carrier-Sense Circuit"
E. Wong (Australian Photonics CRC, THE UNIVERSITY OF MELBOURNE) and M. A. Summerfield (VPI SYSTEMS)

"Strictly Nonblocking Reconfigurable Optical Add-Drop Multiplexers for WDM Networks"
A. V. Tran, W. D. Zhong, R. S. Tucker and K. Song Australian Photonics CRC, THE UNIVERISTY OF MELBOURNE

"All-optical Regenerative Time-Multiplexed Signal Generator"
M. Attygalle and A. Nirmalathas, Australian Photonics CRC, THE UNIVERSITY OF MELBOURNE

"Optical Crosstalk in WDM Fibre-Radio Networks"
D. Castleford, A.Nirmalathas, D.Novak and R. S.Tucker, Australian Photonics CRC, THE UNIVERSITY OF MELBOURNE

"OADM Architecture with Fiber-Bragg Gratings for a Wavelength Interleaved Millimetre-wave Fibre-Radio System"
C. Marra, A. Nirmalathas, D. Novak, C. Lim (Australian Photonics CRC, THE UNIVERSITY OF MELBOURNE), L. Reekie, J. Besley, N. Baker (JDS Uniphase, SYDNEY).

SESSION 3 Dr Malin Premaratne

"Automated Synthesis of WDM Links from Network Level Specifications"
A. J. Lowery and P. Harshavardhana, VPI SYSTEMS, New Jersey, USA.

"Resource Sharing Pool for Recovery Mechanisms of Multi-layer Survivable Networks"
K. Long, R. Tucker (CUBIN, THE UNIVERSITY OF MELBOURNE), S. Cheng, R. Zhang (BEIJING UNIVERSITY OF POST AND TELECOMMUNICATIONS)

"Filtered GIBBS Sampler for Optical Networks",
L. H. Andrew and F. J. Vázquez-Abad, CUBIN, THE UNIVERSITY OF MELBOURNE

"A Lifetime Quantification Tool for WDM Networks"
N. Maxemchuk, T. Shum, A. Zalesky and M. Zukerman, CUBIN, THE UNIVERSITY OF MELBOURNE

The CUBIN Seminar Program has proved to be a valuable opportunity for CUBIN staff and students to present their work to fellow researchers. The weekly seminars also allow visitors and collaborators to share their findings and insights regarding their own areas, as well as reporting on conferences attended elsewhere. Staff and students have the opportunity to liaise with other researchers who are examining similar projects. This popular program of seminars will return in 2002.

2001 Seminar and Lecture Program

INTERNATIONAL SPEAKERS	TITLE	DATE
Lek Ariyavisitakul *Broadband Wireless Solutions, Alpharetta, Georgia, USA Turbo*	Space-Time Processing To Improve Wireless Channel Capacity-Another Shannon-Theoretic View of BLAST	24/4/01
Mansoor Shafi *Telecom New Zealand*	On the capacity of MIMO Systems	23/5/01
Professor Sanjay Bose *Indian Institute of Technology Kanpur*	Analytical Modeling of WDM Optical Cross-Connects (OXC) with Limited Conversion Capability	20/6/01
Professor Michael Honig *Northwestern University*	Adaptation in CDMA Wireless Networks	1/8/01
Felisa Vazquez-Abad *University of Montreal*	Simulation Matters	24/10/01
Steven Low *Caltech University*	Internet Congestion Control	11/12/01

NATIONAL SPEAKERS	TITLE	DATE
Alex Grant *Institute for Telecommunications Research*	Advanced Radio Technologies	17/1/01
Dr Farzad Safaei *Telstra Research Labs*	Carrier-scale Programmable Networks: Wholesaler Platform and Resource Optimization	24/1/01
Girish Nair *The University of Melbourne*	Estimation and Control with Low Data Rates	31/1/01
Arthur Lowery *Virtual Photonics*	Software for design and planning of Optical Networks	7/2/01
Ravi Ranasinghe *CUBIN*	Medium access control packet scheduling in wireless multimedia LANs	14/2/01
	Scheduling disciplines for multimedia WLANs: Embedded round robin and Wireless dual queue	
Fraser Cameron *CUBIN*	Traffic engineering issues in the design and development of multi-media wireless access networks	27/2/01
Lidong Huang *The University of Melbourne*	Analysis and Modeling of TCP/IP traffic	21/3/01
Rajendran Parthiban *CUBIN*	Network Modelling	27/3/01
Christian Fenger *The University of Melbourne*	Dynamical All-Optical Networks	4/4/01
John Leung *CUBIN*	Multiuser detection in wireless data networks	11/4/01
Taka Sakurai *CUBIN*	Estimating tail probabilities when the components are heavy-tailed: applications to outage probability and waiting time	2/5/01
Bui Ngoc Thanh *CUBIN*	Optimal power control in CDMA over Markov fading channels	9/5/01

NATIONAL SPEAKERS	TITLE	DATE
Rami Mukhtar *CUBIN*	Internet Transport over Cellular Networks - An Analytical Insight	16/5/01
Azzam Barakat *CUBIN*	Mobility Modelling and Analysis in CDMA Cellular Systems Using Smart Antennas	22/5/01
Moshe Zukerman Bartek Wydrowski *CUBIN*	MMPP models for GPRS	6/6/01
Lachlan Andrew *CUBIN*	Importance sampling by a non-mathematician	13/6/01
Laurence Park *CUBIN*	Analysis and extraction of useful information across networks of Web databases	27/6/01
David Hayes *The University of Melbourne*	Congestion Management of Packet Switched Networks: Dual Queue approach	4/7/01
Malcolm Peh *CUBIN*	Dimensioning Cellular Spread Spectrum Networks	11/7/01
Tao Peng *CUBIN*	Adjusted Probabilistic Packet Marking For IP Traceback	25/7/01
Ron Addie *University of Southern Queensland*	Network Design	8/8/01
Sarah Dods *The University of Melbourne*	Lies, Damn Lies and Statistics	16/8/01
Laurence Park *CUBIN*	Internet Document Filtering using Fourier Domain Scoring	22/8/01
Chuan Heng Foh *CUBIN*	An Efficient Protocol for Gigabit Local Area Networks	5/9/01
Margreta Kuijper *The University of Melbourne*	A Unifying System-Theoretic Framework for Errors-and-Erasures Reed-Solomon Decoding	12/9/01
Bruce Bayley *Melbourne Enterprises International*	From Benchtop to Commercial Success	26/9/01
Prof. Ian Williamson *Department of Geomatics* Dr Allison Kealy *Lecturer in Global Positioning Systems* Ms Jessica Smith *PhD student* *The University of Melbourne*	An overview of trends in Geomatic Engineering which is evolving into the spatial or geographic dimension of IT	10/10/01
Jolyon White *CUBIN*	The OPNET Modeler Simulation Package	17/10/01
Rami Mukhtar *CUBIN*	A Model for TCP Behaviour over Cellular Radio Channels with Link Layer Error Recovery. Analysis of TCP Performance over Hybrid Fast Fixed - to – Slow Wireless" Buffered Links	31/10/01
Jamie Evans *CUBIN*	Optimal Resource Allocation for Pilot-Symbol-Aided Multiuser Receivers in Rayleigh Faded CDMA Channels	7/11/01
Jia Weng *CUBIN*	The Shortest Network Problem	14/11/01
Attila Pasztor *The University of Melbourne*	Part I: PC Based Precision Timing Without GPS	5/12/01
Attila Pasztor *The University of Melbourne*	Part II: PC Based Precision Timing Without GPS	12/12/01

Public Lecture by Steven Low

Dr Steven Low, Associate Professor in Computer Science and Electrical Engineering at Caltech, USA presented a public lecture on Internet Congestion Control on December 11, 2001. This lecture delved into the goals of congestion control, and how an understanding of TCP and AQM can be developed to include a linear model that studies the dynamics of a network system in equilibrium. He proposed that a scalable TCP/AQM protocol would maintain stability for arbitrary delay, capacity and routing, whilst keeping network queues low and highly utilized in equilibrium.

COLLABORATIONS, LINKAGES AND END-USER GROUP LIAISON

International Visitors

Lek Ariyavisitakul	*Broadband Wireless Solutions, Georgia, USA*
Steven Low	*California Institute of Technology (Caltech), USA*
Professor Sanjay Bose	*Indian Institute of Technology, Kanpur India*
Professor Michael Honig	*Northwestern University, USA*
Ahn, Byong –Yub Seong-Gon Choi Junkyun Choi Minho Kang Manseop Lee Se-yoon Oh Hongshik Park Yonghyub Won	*Optical Internet Research Centre, Information and Communications University, Korea*
Meiping Feng	*Peking University, China*
Mansoor Shafi	*Telecom, New Zealand*
Felisa Vazquez-Abad	*University of Montreal*

National Visitors

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Alex Grant	*Institute for Telecommunications Research, University of South Australia*
Thanh Ngo	*Pacific Broadband Networks*
Ziggy Switkowski Hugh Bradlow	*Telstra*
Farzad Safaei Kerry Hinton Paul Kirton	*Telstra Research Laboratories*
Peter Taylor Lang White	*University of Adelaide*
Ron Addie	*University of Southern Queensland*
Louis Trichard	*University of Sydney*
Farzad Safaei	*University of Wollongong*
Arthur Lowery Malin Premaratne Mark Summerfield	*Virtual Photonics*

Other Collaborators

INTERNATIONAL

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Stefano Buzzi	*University of Cassino*
Sammy Chan	*City University, Hong Kong*
Michael Honig	*Northwestern University*
Robert Karlsson	*Royal Institute of Technology, KTH, Sweden*
Marco Lops	*University of Cassino*
Steven Low	*Caltech, USA*
Rudolf Mathar	*University of Aachen, Germany*
Nick Maxemchuk	*AT&T Laboratories*
Beatrice Meini	*University of Pisa, Italy*
Walter Neumann	*Columbia University*
Vincent Poor	*Princeton University*
Jim Reilly	*McMaster University*
Brooke Shrader	*Royal Institute of Technology KTH, Sweden*
David Tse	*U, C., Berkeley*
Phillip Whiting	*Bell Laboratories Lucent Technologies*
Gerhard J Woeginger	*University of Twente Math Dept*
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NATIONAL

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Tom Chae	*The University of Melbourne*
Iain Collings	*University of Sydney*
Rob Evans	*The University of Melbourne*
Paul Fitzpatrick	*Telstra Research Laboratories*
Richard Harris	*RMIT, Australian Telecommunications CRC*
Kerry Hinton	*Telstra Research Laboratories*
Milosh Ivanovich	*Telstra Research Laboratories*
Thas Nirmalathas	*The University of Melbourne*
Iradj Ouveysi	*Telstra Research Laboratories*
Rob Pattie	*Telstra Research Laboratories*
Farzad Safaei	*University of Wollongong*
Peter Taylor	*University of Adelaide*

The exchange of ideas between researchers and institutions is one of the fundamental underpinnings of leading edge research. CUBIN is committed to encouraging these linkages. Throughout 2001, CUBIN staff and students entered into discussions with researchers from around the world. The results of these collaborations can be seen in the numerous papers co-authored by CUBIN researchers with members of other institutions. Furthermore, exposure to the current research direction in other institutions enables CUBIN researchers to participate in the forefront of international research, and enriches our own projects.

The Optical Internet Research (OIRC) and CUBIN signed a collaboration agreement in 2001. The OIRC is located at the Information and Communications University, and ICU is a Korean National Engineering Research Centre of Excellence. As a part of this collaboration agreement, researchers from each group will participate in collaborative exchanges. The first exchange began in December 2001 with two PhD students, Se-yoon Oh and Seong-Gon Choi taking residence in CUBIN for 3 months.

CUBIN is strengthening its linkages with the Australian Telecommunications CRC and the Australian Photonics CRC. Collaborations with the ATCRC are currently being established in the areas of coding, wireless channel equalization, and optical networking. Collaborations with the Photonics CRC have commenced in the optical networking area. A formal collaboration agreement is also under development with Columbia University, USA.

In 2002 Professor Marcel Neuts and Dr Zvi Rosberg will be undertaking extended visits to CUBIN. Professor Neuts has been awarded a Miegunyah Distinguished Visiting Fellowship in support of his visit to CUBIN.

Industry and other end-user group liaison

The level of interaction between CUBIN and industry continued to grow in 2001. Industry personnel serve on the CUBIN Advisory Board and have made many contributions in other areas. CUBIN and Australian Photonics CRC Photonics Research Laboratory are collaborating on a research contract with Telstra. Many of CUBIN's core research projects involve collaborations with industry, and industry researchers are regular speakers and attendees at the CUBIN seminar series.

The CUBIN strategic plan provides a number of performance indicators to be used in assessing the achievements of the Centre. The table below shows the achievements of CUBIN against key performance indicators in 2001 and compares these with the goals as set out in the original 1999 CUBIN proposal.

PERFORMANCE INDICATORS	YEAR 2 GOAL	YEAR 2 ACTUAL
Number of Principal Research Fellows	1	0
Number of Senior Research Fellows	4	1
Number of Research Fellows	6	8
Industry members on Executive Committee	1	0
Percentage of staff located in close proximity	80%	100%
Percentage of interdisciplinary projects	70%	70%
Percentage of projects involving collaborations with other institutions	30%	50%
Number of joint papers published	10	25
Number of journal papers	30	40
Number of conference papers	30	53
Number of academic visitors	15	18
Number of industry visitors	10	11
Number of workshops and short courses	2	2
Number of institutions in exchange program	2	1
Number of short-term visits to overseas laboratories	15	15
Number of research contracts	3	2
Industry-sponsored scholarships and APA(I)'s	5	6
Number of industry co-supervisors	2	1
Number of graduate students	20	28
Number of Centre graduate student scholarships awarded	3	6
Number of public lectures	2	2
Number of general interest articles	2	2
Number of consultations to government	3	2
Number of exchange visitors in Centre	2	2
Number of Centre researchers on exchange	4	3
Number of conferences	1	1
Student and research fellows with mentors	100%	100%

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In 2001, there were 12 academic teaching staff members and 9 Research Fellows associated with CUBIN. Academic staff members in CUBIN are associated with the Department of Electrical and Electronic Engineering, the Department of Computer Science and Software Engineering, and the Department of Mathematics. Seven of the 9 Research Fellows were funded by the ARC grant. The remaining Research Fellows were funded from other sources.

Director:

Professor Vikram Krishnamurthy (September-December, 2001)

Professor Rod Tucker (January-August, 2001)

Academic Staff:

Dr Natashia Boland

Dr Marcus Brazil

Dr Subhrakanti Dey

Dr Jamie Evans

Dr Stephen Hanly

Professor Rao Kotagiri

Dr M. Palaniswami

Associate Professor Doreen Thomas

Professor Moshe Zukerman

Administration Staff:

Melinda Cartwright

Jan Richardson-Brown

Research Fellows:

Dr Lachlan Andrew

Dr Chandra Athaudage

Dr Brian Krongold

Dr Chris Leckie

Dr Keping Long

Dr Jonathan Manton

Dr Jia Weng

Dr Hai Le Vu

Dr Qinghe Yin

Staff Biographies

LACHLAN ANDREW

Lachlan Andrew received the BE, BSc and PhD degrees in 1992, 1993 and 1996, all from the University of Melbourne. In 1996 and 1997, he was a lecturer in communication networks at RMIT in Melbourne before returning to the University of Melbourne as a research fellow. His research interests are in teletraffic analysis of communication networks and fast simulation techniques.

CHANDRANATH ATHAUDAGE

Chandranath Athaudage received the B.Sc.Eng degree in electronic and telecommunication engineering with first class honours from the University of Moratuwa, Sri Lanka in 1991, and M.Sc. degree in information science from the Japan Advanced Institute of Science and Technology, Hokuriku, in 1997. He completed his Ph.D. studies at Royal Melbourne Institute of Technology (RMIT), Melbourne, in 2001.

During 1992-1994 he was an assistant lecturer at University of Moratuwa, and during 1999-2001 he was a lecturer at RMIT University. Since July 2001, he has been with Centre for Ultra-Broadband Information Networks, University of Melbourne. His research interests include OFDM for wireless multimedia communication, channel estimation and synchronization, and signal modeling and compression.

MARCUS BRAZIL

Dr. Marcus Brazil is a lecturer in the Department of Electrical and Electronic Engineering at The University of Melbourne. He studied English and Mathematics as an undergraduate at The University of Melbourne, and received a Ph.D. in Mathematics (in the field of Computational and Geometric Group Theory) from La Trobe University in 1995.

These days his main research interest is in Optimal Network Design with applications to Telecommunications, VLSI Physical Design, and Underground Mining. Until recently he was a Research Fellow with the Department of Mathematics and then the Department of Electrical and Electronic Engineering at the University of Melbourne. He also does occasional consultancy work for mining companies such as Normandy Mining Limited.

SUBHRAKANTI DEY

Subhrakanti Dey was born in Calcutta, India in 1968. He obtained his Bachelor of Technology and Master of Technology degree from the Dept. of Electronics and Electrical Communication Engineering, Indian Institute of Technology, Kharagpur, India, in 1991 and 1993 respectively. He obtained his Doctor of Philosophy degree from the Dept. of Systems Engineering, Research School of Information Sciences and Engineering in the Australian National University, Canberra, Australia in 1996.

He is currently appointed as a Senior Lecturer with the Department of Electrical and Electronic Engineering in the University of Melbourne where he has been since February 2000. During September 1995-September 1997 and September 1998-February 2000, he was appointed as a postdoctoral Research Fellow in the Department of Systems Engineering, Australian National University. During September 1997-September 1998, he was a post-doctoral Research Associate at the Institute for Systems Research, University of Maryland, College Park, U.S.A. His current research interests include signal processing for telecommunications, wireless communications and networks, performance analysis of communication networks, stochastic and adaptive estimation and control and statistical and adaptive signal processing. He is currently an academic staff member of the ARC Special Research Centre for Ultra-Broadband Information Networks in the Department of Electrical and Electronic Engineering, University of Melbourne.

JAMIE EVANS

Jamie Evans received the Bachelor of Science degree in Physics and the Bachelor of Engineering degree in Computer Engineering from the University of Newcastle, Australia in 1992 and 1993 respectively, and received the University Medal in Computer Engineering upon graduation. He then moved to the University of Melbourne, Australia where he received a Masters degree in 1996 and the Ph.D. degree in 1998 both in Electrical Engineering and was awarded the Chancellor's Prize for Excellence in the Ph.D. thesis. From March 1998 to June 1999 he was a Postdoctoral Fellow at the University of California, Berkeley. Upon returning to Australia he took up a position as Lecturer at the University of Sydney. Since July 2001, he has been a Senior Lecturer in the Department of Electrical and Electronic Engineering at the University of Melbourne. His research interests are in communications and information theory and statistical signal processing with current focus on wireless communications networks.

VIKRAM KRISHNAMURTHY

Vikram Krishnamurthy was born in 1966. He received his bachelor's degree in Electrical Engineering from the University of Auckland, New Zealand in 1988, and doctoral degree from the Australian National University, Canberra in 1992. He is currently a Professor at the Department of Electrical Engineering, University of Melbourne, Australia and also serves as deputy head of department. His research interests span several areas including stochastic scheduling and network optimization, time-series analysis, and statistical signal processing in wireless networks.

Dr. Krishnamurthy is currently an associate editor for IEEE Transactions on Signal Processing and Systems and Control Letters. He has served on the technical program committee of several conferences including the 37th IEEE Conference on Decision and Control, Tampa, Florida, 1998 and IFAC Symposium on System Identification in 2000 (SYSID'2000), Santa Barbara, USA.

BRIAN KRONGOLD

Brian Scott Krongold received the B.S. (with honors), M.S., and Ph.D. degrees in electrical engineering in 1995, 1997, and 2001, respectively, from the University of Illinois at Urbana-Champaign, where he worked toward the Ph.D. degree as a Research Assistant at the Coordinated Science Laboratory. During the summer of 1994, he interned for Martin Marietta at the Oak Ridge National Laboratory, Oak Ridge, Tennessee. From January to August of 1995, he consulted at Bell Laboratories in Middletown, New Jersey. During the summer of 1998, he worked at the Electronics and Telecommunications Research Institute, Taejon, South Korea, under a National Science Foundation summer research fellowship. During the spring semester of 1999, he was a Visiting Research Assistant in the Department of Electrical and Computer Engineering at Rice University, Houston, Texas.

Currently, he is a Research Fellow at the ARC Special Research Centre for Ultra-Broadband Information Networks at the University of Melbourne, Australia. He received the second

prize in the student paper contest at the 2001 Asilomar Conference on Signals, Systems, and Computers. His research interests are in multicarrier communication systems, wavelets and filterbanks, and optical communications.

CHRIS LECKIE

Chris Leckie has been a Senior Research Fellow in CUBIN since 2000. He received his BSc, BE(Hons) and PhD in artificial intelligence (AI) from Monash University in Melbourne. Previously, he worked at Telstra Research Laboratories in Melbourne for 12 years, where he was a researcher and project leader on projects using AI for network management, information retrieval and other telecommunication applications. His current research interests include using AI for network intrusion detection, network management, active networks and optical networking.

KEPING LONG

Keping Long received his PhD degree in 1998 from University of Electronic and Science Technology of China (UESTC). From Sept. 1998 to Aug. 2000, he worked as a postdoctoral research fellow at National Laboratory of Switching Technology and Telecommunication Networks in Beijing University of Posts and Telecommunications (BUPT). From Sept. 2000 to June 2001, he was an Associate Professor in Beijing University of Posts and Telecommunications (BUPT). From July 2001 to the present, he is a Research Fellow in ARC Special Research Centre for Ultra Broadband Information Networks (CUBIN) in the University of Melbourne.

His research interests include: Optical Burst switching, modeling of optical networking, router queue management and fair scheduling algorithm, IP QoS mechanisms (Diffserv and Intserv, MPLS), WDM/SDH/ATM networks survivability, ATM/IP networks performance analysis, TCP/IP enhancements in wireless networks, Mobile IP. He has over 50 research publications and has finished eight projects as a key researcher and a project manager. He also has four patents application and two translated books. He is an IEEE member and was an academic secretary of " Network and Information Security " key research programming supported by the national science foundation of China (NSFC).

JONATHAN MANTON

Dr Manton received his Bachelor of Science (mathematics) and Bachelor of Engineering (electrical) degrees in 1995 and his Ph.D. degree in 1998, all from the University of Melbourne, Australia. In 2000 he became a holder of the prestigious Research Fellow Award by the Australian Research Council, which he chose to take up at the University of Melbourne. His current research interests include precoding for wireless communications, rank constrained filtering, optimisation on manifolds, statistical learning theory and stochastic optimisation. He is currently an associate editor, conference editorial board, IEEE Control and Systems Society.

DOREEN THOMAS

Associate Professor Doreen Thomas is Head of the Department of Electrical and Electronic Engineering at the University of Melbourne. She received a B.Sc.Hons at the University of Witwatersrand, South Africa, then went on to graduate with the D.Phil.Degree in Mathematics at Oxford University in 1977. Doreen is in charge of the Mathematics for Engineers program at the University of Melbourne.

Her research in Optimal Network Design has applications in Telecommunications, VLSI Physical Design and Underground Mining.

RODNEY S. TUCKER

Rodney S. Tucker is the Founding Director of CUBIN. He is also associated with the Australian Photonics Cooperative Research Centre. From 1973 to 1975 he was a Lecturer in Electrical Engineering at the University of Melbourne. During 1975 and 1976 he was a Harkness Fellow with the Department of Electrical Engineering and Computer Sciences, University of California, Berkeley and from 1976 to 1977 he was a Harkness Fellow with the School of Electrical Engineering, Cornell University, New York. From 1977 to 1978 he was with Plessey Research (Caswell) Ltd., UK, and from 1978 to 1983 he was with the Department of Electrical Engineering at the University of Queensland, Brisbane, Australia. From 1984 to 1990 he was with AT&T Bell Laboratories, Crawford Hill Laboratory, Holmdel, NJ and in 1990 he joined the Department of Electrical and Electronic Engineering at the University of Melbourne.

Dr. Tucker was Editor of the IEEE Transactions on Microwave Theory and Techniques, and is currently an Associate Editor of Photonics Technology Letters. He is a Fellow of the IEEE, a Fellow of the Australian Academy of Technological Sciences and Engineering, and a Fellow of the Australian Academy of Science. In 1997 he was awarded the Australia Prize for his contributions to telecommunications.

HAI LE VU

Hai Le Vu received the M.Sc. and Ph.D. degree in Electrical Engineering, from the Technical University of Budapest, Hungary, in 1994 and 1999, respectively. From 1994 to 2000, he was a research engineer in Siemens AG, Hungary. From 2000 to the present, he is a research fellow in Centre for Ultra Broadband Information Networks (CUBIN), the Department of Electrical Engineering, at the University of Melbourne, Australia. His research interests are in wireless networks, data network modelling and performance, optical network design, queuing theory and the Internet.

JIA WENG

Jia Weng received his PhD at the Flinders University of South Australia in 1994. He then became a research fellow in the Department of Mathematics at the University of Melbourne, where he was involved in studying the shortest network problem and its applications (1994-2000). In 2001 he joined CUBIN in the Department of Electrical and Electronic Engineering at the University of Melbourne, where he has undertaken research in the increasingly important area of Telecommunications.

MOSHE ZUKERMAN

Moshe Zukerman received his B.Sc. in Industrial Engineering and Management and his M.Sc. in Operation Research from Technion - Israel Institute of Technology and a Ph.D. degree in Electrical Engineering from The University of California Los Angeles in 1985. Dr. Zukerman was an independent consultant with IRI Corporation and a post-doctoral fellow at UCLA during 1985-1986. During 1986-1997 he served in Telstra Research Laboratories (TRL), first as a research engineer and between 1988-1997 as a project leader managing a team of researchers providing expert advice to Telstra on network design and traffic engineering, and on traffic aspects of evolving telecommunications standards.

He is the recipient of the Telstra Research Laboratories Outstanding Achievement Award in 1990. In 1997 he joined The University of Melbourne where he is responsible for promoting and expanding telecommunications research and teaching in the Electrical and Electronic Engineering Department. Since 1990, he has also taught and supervised graduate students at Monash University. He is an IEEE Senior Member and has served as a session chair and member of technical and organizing committees of numerous national and international conferences. He gave tutorials in several major international conferences such as IEEE ICC and IEEE GLOBECOM. He served on the editorial board of the Australian Telecommunications Research Journal during 1991-1996. He also served as a Guest Editor of IEEE JSAC for two issues: Future Voice Technologies and Analysis and Synthesis of MAC Protocols. Presently, he is serving on the editorial board of the IEEE/ACM Transactions on Networking, the International Journal of Communication Systems, Computer Networks, and as a Wireless Communications Series Editor for the IEEE Communications Magazine. He submitted contributions to and represented Australia in several ITU-T/CCITT standards meetings. Dr. Zukerman has over 150 publications in scientific journals and conference proceedings and has been awarded several national and international patents.