# Table of Contents

**Head’s Introduction** ................................................................................................. 2

**Computer and Software Engineering** ..................................................................... 4
- Computing and Audio Research Laboratory .......................................................... 4
- Image Processing Laboratory .................................................................................. 11
- Software Engineering Laboratory .......................................................................... 15
- Web Engineering Group ......................................................................................... 20

**Fibre-optics and Photonics Laboratory** ................................................................. 23

**Centre of Excellence in Power Engineering** ......................................................... 31

**Telecommunications Laboratory** ......................................................................... 37
Head’s Introduction

Prof Branka Vucetic: Head of School

The School of Electrical and Information Engineering undertakes cutting-edge research across a wide range of engineering and information technology sub-disciplines.

Computer and Software Engineering research is being undertaken in the areas of integrated circuit design, low power VLSI, neuro-morphic engineering, modelling of biological visual and auditory pathways in software and silicon, smart sensors, audio research, augmented and virtual reality (3D) audio, human sound localisation, acoustics of listening spaces, multi-channel (64) loudspeaker playback, video and audio communication over wired and wireless/mobile network, software architecture, distributed components and middleware, real-time systems and performance engineering diverse applications in signals and systems with particular emphasis on image processing, and web engineering.

The Fibre-optics and Photonics Laboratory (FPL) specialises in research into advanced optical techniques for information systems. This focuses on fundamental research in areas including photonic signal processing, optical communications, microwave photonics, nonlinear fibre optics, optical network security and encryption, optically-controlled phased arrays, and terahertz/gigahertz photonics in communication and radar systems.

The Telecommunication Laboratory carries out research in a broad area of wireless communication systems, including transmission, adaptive signal processing, protocols, routing, network architectures, network security, location estimation and network traffic modelling. The research outcomes have wide applications in satellite, cellular, sensor and intelligent power networks.

Power Engineering focuses on advanced electronic control of electricity grids using utility power electronics, electrical energy storage and generation with sustainable energy sources such as wind, solar and fuel-cell, direct current microgrids and high-voltage direct-current power transmission topologies and control. The main theme of the research is centred on increased energy efficiency and new technologies to support the intelligent grid. The phenomenal growth of the power engineering field at the University of Sydney, over the least three years, has been recently consolidated as a University recognised Centre of Excellence in Power Engineering. The Centre enjoys strong industrial support from many key players in Australia and internationally.

The innovative, collaborative, cross disciplinary research detailed above is a hallmark of the School’s research, which integrates a diverse array of approaches, supported by excellent infrastructure and
builds strong links with industry. The research productivity of the School is outstanding by any international comparison, with many DEST publications, the majority of which were in internationally recognised peer-reviewed journals. Success in competitive grant funding is high and continues to rise. In the last funding round the School was awarded six ARC grants totalling $1795 K and achieved a success rate of 42%, well above the national average.

Senior academic leadership is provided by two Personal Chairs (Minasian, Vucetic), both of whom are IEEE Fellows, and the Energy Australia-funded Chair of Power Engineering (Agelidis). In addition, the School has another IEEE Fellow, three QEII Research Fellows, one APD Fellow and a wide range of honorary, adjunct and emeritus appointments with strong industry links to ensure research remains relevant to real world demands.
Computer and Software Engineering

Computing and Audio Research Laboratory

The Computing and Audio Research Laboratory (CARlab) specialises in three main research areas: "Neuromorphic Engineering", “BioElectronics”, and "Spatial Audio".

Neuromorphic Engineering is concerned with the study of signal processing in biological (neural) systems and applying principles learned from biology in electronic systems. Typical examples are smart sensory systems where integrated circuits (mostly analogue or mixed-mode VLSI) have been implemented. They have been inspired by models of the visual or auditory systems of particular animals. CARlab is one of the top ten research labs in the world in this area and the top neuromorphic engineering group in Australia.

Our BioElectronics research aims to develop hardware and algorithms to measure and classify biological signals, such as ECG, EMG, EEG, 3D position and location, skin conductivity, and blood oxygenation. We are researching a portable Electronic Impedance Tomography Spectroscopy device which measures tissue impedance to create an image of the tissue impedance distribution. This EITS system can be used, for instance, for monitoring stroke, epilepsy, and for detecting cancer.

Our Spatial Audio research deals with all aspects of the spatial perception of sound. This includes the study of how humans localise sounds, the effect of room acoustics on sound perception, recording of spatial sound fields, playback using our 64 loudspeaker array, generation of augmented and virtual reality audio, 3D voice communication systems with location aware computing, and the study of musical aspects of sound fields. Applications of this research are in music recording and playback, video games, teleconferencing, and hearing aids.

Personnel

Academic staff:

- Dr André van Schaik, Reader & QEII Research Fellow
- Dr Craig Jin, Senior Lecturer & QEII Research Fellow
- Dr Alistair McEwan, Lecturer.

Researchers and postgraduate students:

- Dr Nicolas Epain, Postdoctoral Research Fellow
- Dr Virginia Best, Postdoctoral Research Fellow
- Mr Xiao Feng Dong, PhD Student
Research School of Electrical and Information Engineering

- Mr Alan Kan, PhD Student
- Mr Sean Luskey, PhD Student
- Mr Aengus Martin, PhD Student
- Mr Abhaya Parthy, PhD Student
- Mr David Sun, PhD Student
- Mr Pat Taweewat, PhD Student
- Mr Andrew Wabnitz, PhD Student
- Mr Ping Kun Tony Wu, PhD Student.

Research Achievement and Activities

- Tara Julia Hamilton graduated in December 2008 with the degree of Doctor of Philosophy. Her thesis is entitled: “Analogue VLSI Implementations of Two Dimensional, Nonlinear, Active Cochlea Models”

Abstract: This thesis presents my work from the last 4 years on active, nonlinear two dimensional (2D) silicon cochlea modelling. It begins with an introduction on what is currently understood about the active and nonlinear characteristics of the mammalian cochlea and proceeds to develop an active, 2D cochlea model which incorporates these characteristics. Of particular importance in the model is the idea that the cochlear amplifier (CA) has dynamics governed by the Hopf equation. The realisation of the active 2D model leads to several hardware implementations that are based on two slightly different but equivalent approaches.

In the first approach, I propose an implementation of the Hopf equation based on its equivalence with changing the quality factor (Q) in a second-order band-pass filter. This implementation is called Automatic Quality Factor Control (AQC) and we show that it not only has the dynamics of a system that is governed by the Hopf equation but also that it represents a type of parametric amplification. Parametric amplification is characterised by its robustness to both noise and a wide range of phase shifts. AQC is an intuitive approach where the feedback loop explicitly adds or subtracts energy from the system based on the intensity of the input signal. Two silicon cochleae were made based on this approach. Both of these silicon cochleae were the first silicon cochleae to exhibit large signal compression, two-tone suppression and the creation of combinational, odd-ordered distortion products. The second silicon cochlea with AQC also facilitated a study into the effects of coupling between basilar membrane (BM) resonator sections.

In the second approach, I propose an implementation based on implicitly modelling the Hopf equation as a Hopf Oscillator. In this approach there is no visible control-loop, however, the Hopf oscillator possesses the same dynamics as the AQC implementation. A silicon cochlea based on this approach was built and tested and, as expected, it exhibits the same nonlinear, active characteristics as the silicon cochlea with AQC. With this implementation I was able to further explore coupling in the cochlea. I was also able demonstrate masking as well as high quality factors comparable with biology.
Together, this body of work provides the foundations for a silicon cochlea that can be used to better understand the biological cochlea as well as explore higher auditory centres.

- Vincent Chan graduated in May 2009 with the degree of Doctor of Philosophy. His thesis is entitled: “Audio-visual sensor fusion for robotic source localisation”

**Abstract:** The object of this thesis is to investigate audio-visual sensor fusion using neuromorphic implementations. We present a sound localisation system consisting of a pair of silicon cochleae and a neuromorphic vision sensor on a robotic platform. The combination of audio and visual sensors allows a robot to learn to localise sound sources via self-motion and visual feedback in a noisy and echoic environment. The work presented in this thesis includes the design and the characterisation of a silicon cochlea and a vision sensor, the design of a sound localisation algorithm, and their integration on the robotic platform. Both the silicon cochlea and the vision sensor operate with the address-event representation interface. The vision sensor uses a novel configuration of the winner-take-all circuit to determine the locations of multiple transient objects. The sound localisation algorithm improves upon previous neuromorphic implementations as it is adaptive, capable of learning, and more biologically realistic. The final system is able to determine the azimuth position of the sound source to within 5° despite the imperfections and limitations of the sensors, and the presence of noise and reverberation in its operating environment.

- In April 2009, we published: A Kan, C Jin, and A van Schaik “A psychophysical evaluation of near-field virtual auditory space derived from far-field head-related transfer functions,” in the *Journal of the Acoustical Society of America*.

**Abstract:** A method for synthesizing near-field head-related transfer functions (HRTFs) from far-field HRTFs measured using an acoustic point source of sound is presented. Near-field HRTFs are synthesized by applying an analytic function describing the change in the transfer function when the location of a sound source changes from the far-field to the near-field: the distance variation function (DVF). The DVF is calculated from a rigid sphere model and approximates the change in the frequency-dependent interaural level cues as a function of the change in sound source distance. Using a sound localization experiment, the fidelity of the near-field VAS generated using this technique is compared to that obtained by simply adjusting the intensity of the VAS stimulus to simulate changes in distance. Results show improved distance perception for sounds at simulated distances of up to 60 cm using the DVF compared to simple intensity adjustment, whilst maintaining directional accuracy. The largest improvement for distance perception was for sound sources located to the side and within 40 cm. When intensity was removed as a cue for sound source distance from near-field sounds generated using the DVF, results showed some discrimination of sound source distances but, in general, distance perception accuracy was poor.

- In June 2009 we published: J Tapson, C Jin, A van Schaik and R Etienne-Cummings, “A first-order non-homogeneous markov model for integrate-and-fire neurons stimulated by small phase-continuous signals,” in *Neural Computation*.
Abstract: We present a first-order non-homogeneous Markov model for the interspike interval density of a continuously stimulated integrate-and-fire neuron. The model allows the conditional interspike interval density and the stationary interspike interval density to be expressed as products of two separate functions, one of which describes only the neuron characteristics, and the other of which describes only the signal characteristics. The approximation shows particularly clearly that signal autocorrelations and crosscorrelations arise as natural features of the interspike interval density, and are particularly clear for small signals and moderate noise.

Research Funding

- Dr S-C Liu and Dr A van Schaik, “Multimodal Sensor Fusion with Spiking Neuromorphic Sensors,” Office of Naval Research, in collaboration with the Swiss Federal Institute of Technology, Zurich, $245k, 2006-2009
- Dr C Jin and Dr A van Schaik, “Broadcasting 3D Audio: Recording, Transmission, and Playback,” ARC Discovery Grant, $580k, 2006-2010
- Professor J Shaw, Dr D Del Favero, Professor NC Brown, Professor PJ Compton, Dr M Pagnucco, Dr C Jin, Dr A van Schaik, A/Professor HS Seah, Professor P Weibel, Ms S Brution Kenderdine, Mr T Hart, Dr JM Fritz, “Reformulating narrative in virtual heritage using a co-evolutionary model of immersive interactivity,” ARC Linkage Grant, in collaboration with the University of New South Wales, $429k, 2006-2009
- Dr C Jin, A/Professor IS Burnett, “Beamforming with acoustic vector sensors for audio user interfaces,” ARC Discovery Grant, in collaboration with the University of Wollongong, $285k, 2007-2009

Research Facilities

- CARlab has constructed a large semi-anechoic audio playback room (12m x 9m x 3.3m). The characterisation of its acoustics has been performed in collaboration with the Faculty of Architecture, and a journal paper has been prepared on this characterisation. A 32-loudspeaker spherical array has been installed and is now operational. We have started various experiments in the room and we believe we are the first to have created a 16-speaker 2nd order ambisonic playback of a sound field. The room is a unique asset to The University of Sydney. We have also constructed a dual-concentric spherical microphone array with 64 microphones and a 24-channel cylindrical microphone array.
- CARlab also has a soundproof booth and a sound-localisation room for virtual reality audio experiments.
• We have access to an anechoic chamber with a loudspeaker mounted on a robot arm, for sound localisation experiments and measurements. This chamber is in the Auditory Neuroscience Laboratory in the Department of Physiology.
• We have access to a recording studio, a 5.1 listening room, a small anechoic room and a reverberant room from our colleagues in the Faculty of Architecture.

Research Collaboration
• Within the School, we collaborate with the Web Engineering Group in the area of Brain Computer Interfaces
• At The University of Sydney we collaborate intensely on spatial audio research with the Auditory Neuroscience Laboratory in the Department of Physiology, and the Architectural and Audio Acoustics Laboratory in the Faculty of Architecture
• In Australia, we have active collaborations with the iCinema Centre for Interactive Cinema Research at the University of New South Wales, at the Whisper Laboratories at the University of Wollongong, and the Complex and Intelligent Systems Research Group at the University of Queensland
• Internationally, we have collaborations with the University of York, University College London, the Swiss Federal Institute of Technology, Johns Hopkins University, the University of Maryland, and the University of Cape Town.

Awards
• In 2008, André van Schaik was awarded the QEII Research Fellowship by the Australian Research Council
• In 2009, Craig Jin was elevated to Senior Member by the IEEE.

Professional Service

André van Schaik:
• Senior Member: IEEE, Circuits and Systems Society, Solid-State Circuits Society
• Past Chair, IEEE CAS Technical Committee on Sensory Systems
• Member, IEEE CAS Technical Committees: Analogue Signal Processing, Biomedical Circuits and Systems, Neural Systems and Applications
• Board member, Institute of Neuromorphic Engineering
• Past-Secretary, IEEE NSW joint chapter of SSCC and CAS
• Associate Editor IEEE TCAS-I
• Elected member of the EPSRC peer review college
• Organiser Telluride Neuromorphic Engineering Workshop (1998-2009)
• Founding member: VAST Audio P/L, Personal Audio P/L, & Heard Systems P/L
• Advisory board member: Sensory Networks, Inc. Technical advisor.

Craig Jin:
• Senior Member: IEEE, Circuits and Systems Society, Solid-State Circuits Society
• Member: Audio Engineering Society
- Reviewer: JASA, IEEE TCAS I and II, IEEE TNN, NIPS, EWNS, ISCAS, ICASSP, WASPAA
- Founding member: VAST Audio P/L, Personal Audio P/L, & Heard Systems P/L.

**Alistair McEwan:**
- Executive committee of the Centre for neuroimaging techniques (UCL-CNT), London, UK
- Member, IEEE CAS Technical Committee: Biomedical Circuits and Systems.

**Publications**

**Journal Papers:**

**Conference Papers:**


Patents:


Image Processing Laboratory

Research activities in the group centre on applied signals and systems analysis with particular emphasis on image processing. Particular research topics include human face image recognition, medical image processing, and DNA sequence and microarray data analysis.

Signature Image Processing (or SIP) developed by the group, is a novel technique for analysing sampled data sequences. It is currently being applied to gas metal arc welding and resistance spot welding, as well as for processing of external EEG signals in collaboration with Dr Armin Mohamed, Director of the Comprehensive Epilepsy Centre of Royal Prince Alfred Hospital.

An industrial system for fault detection in gas metal arc welding, WeldPrintTM, is being commercialised. The technology, which is based on SIP, won the $100,000 inaugural Peter Doherty Prize for Australasian Innovation in 2003.

Personnel

Academic staff:

- A/Prof Steve Simpson, Associate Professor
- A/Prof David Levy, Associate Professor
- Prof Hong Yan, Honorary Professor
- Dr Didier Debuf, Adjunct Lecturer.

Researchers and postgraduate students:

- Heba Khamis, PhD Student
- Xu Li, PhD Student
- Ilene Chen, PhD Student
- Bruce Poon, MER Student
- Alex Wang, PhD Student.

Visitors:

- Dr K Fukui, Sumitomo Metals P/L
Research Achievement and Activities
The group has carried out research work on image processing and bioinformatics during the year. We have developed efficient computer methods for recognition of human faces, detection of genes and prediction of promoters in DNA sequences and estimation of missing microarray data. A number of papers has been published in international journals and conferences.

As an example, short gene detection in DNA sequences is a well-known difficult problem in bioinformatics. A PhD student, June Jiang, has developed a new algorithm for the analysis of spectral properties of short genes using the wavelet transform and the Hilbert-Huang transform (HHT). A wavelet subspace algorithm combined with the empirical mode decomposition (EMD) is introduced to create subdivided intrinsic mode functions (IMFs) and a cross-correlation analysis is applied to remove pseudo-spectral components. Experiments are carried out on DNA sequences with the double-base (DB) curve representation and the results show that the signal-to-noise ratio of buried signals can be enhanced using the proposed method, yielding significant patterns that are rarely observed with conventional methods. The wavelet subspace Hilbert-Huang transform (WSHHT) algorithm is able to correctly identify spectral patterns of very short genes (below 70 bp) in DNA sequences.

In welding research, globular metal transfer discovered in the 1960’s has been explained in terms of deterministic chaos in metal transfer, and work will continue with linear wave analysis and attractor characterisation. Multigroup discrimination analysis for parametric weld fault detection has yielded significant performance gains and results will be published shortly. In EEG research, a paper showing effective seizure detection with guided autoregressive analysis has been accepted by Clinical Neurophysiology. Work on aurally guided processing for preseizure detection has commenced and is yielding promising results.

Postgraduate completions since 2008:
- Ilene Chen, PhD
- Miew Keen Choong, PhD
- June Jiang, PhD
- Xiaomeng Li, MER
- Yi Wang, MER
- Zhanggui Zeng, PhD.

Research Facilities
- Welding laboratory

Research Collaboration
- Osaka University
- RPAH Comprehensive Epilepsy Centre.
Awards

- Xiaomeng Li, EIE MER student, Yongmei Liu, EIE visiting scholar, and Hong Yan received a merit award for their paper "Eukaryotic promoter prediction based on principal component analysis" presented at the International Multi-Conference of Engineers and Computer Scientists held in Hong Kong in March 2008.

Publications (2008-)

Journal Papers:


Conference Papers:

[16]. X Li, Y Liu and H Yan, "Eukaryotic promoter prediction based on principal component analysis", in Proceedings of Int. Multiconference of Engineers and Computer Scientists, pp 174-178, 2008.


Software Engineering Laboratory

The Software Engineering Laboratory (SEL) specialises in the research areas of configuration and performance of distributed real-time (DRT) systems and components, architecture and middleware (CAM). SEL works closely with the ICT Centre Web Services Group and the Medical Imaging Group at the CSIRO.

The work on the configuration and performance of distributed real-time systems aims to develop innovative technologies of adaptive computing and network resources for large-scale real-time control systems in networked environments. It is significant because it promotes a new vision of design and maintenance of networked control systems, addresses challenges in large-scale networked control systems, develops practical solutions to system adaptation and model-based software engineering methods. Expected outcomes include new task models, methodologies, and model-based software design methods for large-scale adaptive networked control systems.

The CAM group’s objectives are to develop methods and tools which help software developers effectively build loosely-coupled distributed systems, by developing architectures for organising components connected by middleware. The research aims to produce systems that are easy to build and are dependable, that is, the system performs as expected. Our focus is especially on performance, consistency and security issues. That is, we work on frameworks for developers to design the system so they know 1) the resources needed to achieve a given requirement of performance, 2) the system will protect the integrity of data stored in the system, or the integrity of processes managed by the system and 3) that it will be secure against a variety of malicious attacks.

The image processing work is carried out in collaboration with the CSIRO ICT medical imaging group. Our contribution focuses on image segmentation and annotation, markers and their identification with applications to health care. We are participating in building a simulator for virtual surgery and tools for early identification of Alzheimer’s disease.

Personnel

Academic staff:
- A/Professor David C Levy

Current Postgraduate students at December 2008:
- Tian, Yuchu, PhD Student, DRT (submitted), “Object-oriented specification and design for real-time control systems”
- Li, Da Hai, PhD Student, CAM, “DRE middleware”
Postgraduate Research School •

- Rajani, Meena, PhD Student, CAM, “Secure memory services”
- Doma, Eugene, PhD Student, CAM, “A generative programming environment for SOA implementation of adaptive business information systems”
- Seneviratne, Sena, PhD Student, CAM (submitted), “Framework for load profile prediction for grid computing”
- Yao, Jinhui (Kim), PhD Student, CAM (with CSIRO), “Secure data services”
- Raniga, Parnesh, PhD Student, Image processing (with CSIRO), “Quantitative analysis of C-PiB PET: applications to early diagnosis of Alzheimer’s disease”
- Lee, Bryan, PhD Student, Image processing (with CSIRO), “Neuro-simulator for virtual surgery”
- Tam, King, MPhil Student, Image processing, “Automated image segmentation and annotation”
- Wang, Tao, MPhil Student, “WS-security performance”.

**Postgraduate student completions, 2007-8:**

- 2008, Nam, Dong He, MER, CAM, “Automatic test generation of object statecharts”
- 2008, Du, Bing, PhD, CAM, “Robust control real-time scheduling”
- 2007, Garcia Adeva, Juan, PhD, CAM, “A general software architecture for text-mining engineering”,
- 2007, Li, Zhanwen, MER, CAM, “Web services resource management”
- 2007, Sun, Yi Feng, MER, CAM, “UML-RT oriented design approach for Building ERT Systems”.

**Research Achievement and Activities**

- Bing Du graduated in November 2008 with the degree of Doctor of Philosophy. His thesis is entitled: “Robust control real-time scheduling”.

*Abstract:* We developed feedback error learning and H-infinity (FEL-H) control real-time scheduling as a unified framework to provide Quality of Service (QoS) guarantees in open and unpredictable operating environments in which workload and platform may vary significantly at run-time. This framework provides novel robust scheduling architecture to control new QoS critical systems with which traditional scheduling or existing feedback scheduling that uses an ad hoc manner or classical feedback control algorithms cannot cope. A multi-tank system is analysed to simulate a dynamic scheduling model. This model enables us to easily analyse real-time scheduling with various constraints, overload and disturbance.

We developed FEL-H scheduling algorithms for four applications that included real-time CPU scheduling, distributed real-time scheduling, web servers and middleware. These applications are significantly different in performance guarantees, scheduled resources, architecture, and system models. Simulation demonstrates that our algorithms successfully

16
achieved more robust performance guarantees in all applications than traditional feedback scheduling achieved.

- Dong He Nam graduated in November 2008 with the degree of Master of Engineering(Research). His thesis is entitled: “Automatic test generation of object statecharts”.

**Abstract:** The evolution of current UML specifications gives rise to the problem of generating automated test cases from a variety of application tools. Past endeavours on behavioural testing of UML statecharts have not systematically leveraged the potential of existing graph theory for testing of objects. Therefore, there exists a need for a simple, tool-independent, and effective method for automatic test generation.

An architecture, codenamed ACUTE-J (Automated stateChart Unit Testing Engine for Java), for automating the unit test generation process, is presented. A sequential approach for converting UML statechart diagrams to JUnit test classes is described, with the application of existing graph theory. In this research, a direct application of Chinese Postman algorithms on multi-levelled statecharts will demonstrate that it is possible to test statecharts without modifying the original model.


**Abstract:** With the integration of communication networks and distributed control in modern manufacturing and process industries, networked control systems (NCSs) are becoming increasingly important due to their simplicity, scalability, flexibility, and cost-effectiveness. However, there are still significant technical barriers that limit the applications of NCS technologies. Two challenges are network-induced time delay and data packet dropout. Applying a real-time queuing protocol that we developed recently, we are able to limit the sum of the network-induced communication delay and the control computation delay within a control period. This one-period delay is further guaranteed by well-designed compensation for control packet dropout. Then, this paper proposes to compensate for the control packet dropout at the actuator using past control signals. Three model-free strategies for control packet dropout compensation, namely, PD (proportional plus derivative), PD2 (proportional plus up to the second-order derivative), and PD3 (proportional plus up to the third-order derivative) are developed. They are suitable for a large number of NCSs without the need to tune the compensator parameters. The proposed dropout compensation schemes are demonstrated through numerical examples.


**Abstract:** This paper addresses complex real-time networked control systems (NCSs). From our recent effort in this area, a general framework is developed to deal with network complexity. When the complex traffic of real-time NCSs is treated as stochastic and bounded
variables, simplified yet improved methods for robust stability and control synthesis can be developed to guarantee the stability of the systems. From the perspective of network design, over-provisioning of network capacity is not a general solution as it cannot provide any guarantee for predictive communication behaviour, which is a basic requirement for many real-time applications. Co-design of network and control is an effective approach to simplify the network behaviour and consequently to maximize the performance of the overall NCSs. To implement such a co-design, a queuing protocol is applied to obtain predictable network traffic behaviour. Then, the predictable network-induced delay is compensated through the controller design, and any dropped control packet is also estimated in real-time using past control packets. In this way, the network-induced delay can be limited within a single control period, significantly simplifying the network complexity as well as system analysis and design.

Research Collaboration
- Within the Faculty of Engineering and IT, we collaborate with A/Professor A Fekete and Dr U Roehm of the School of IT on Middleware and Database architectures
- With the CSIRO, we collaborate with Dr Shiping Chen, ICT Centre on Web Services Security and with Dr Olivier Salvado, Biomedical Imaging
- Internationally, we work with Bran Selic, Malina Software Corp., Canada on Model-based Software Engineering and with A/Professor Paulo Pires, Brazil and A/Professor Yong Zhong Lu, Huazhong, China on middleware architectures.

Professional Service

David C Levy:
- Member: IEEE, Computer Society
- Member: ACM
- Advisory board member: e-Nose, Inc. Technical advisor.

Publications

Journal Papers:
Conference Papers:


Web Engineering Group

The Web Engineering Group develops systems that learn and help people learn. We are developing learning technologies and collaborative applications that use machine learning algorithms to improve the user experience or produce innovative functionalities.

Our current work includes:
* Text mining functionalities to support collaborative learning
* Affective computing
* Social network analysis
* Computer supported collaborative work and learning
* Brain Computer Interfaces, and other physiological sensing applications.

Personnel

Academic staff:
- Rafael A Calvo, Dr

Researchers and postgraduate students:
- Omar Alzoubi (PhD Student)
- Payam Aghaeiour (PhD Student)
- Sazzad Md Hussain (PhD Student)
- Ming Liu (MPhil Student)
- Sunghwan (Mac) Kim (MPhil Student)
- Stephen O’Rourke (MPhil Student)
- Jorge Villalon (PhD Student).

Research Achievement and Activities

We are developing new approaches for using text mining to improve learning technologies. Our tool, named Glosser, is being used by students in the Faculty.

We are starting to produce outcomes in affective computing. The novel area of affective computing aims at making computers aware of the mental states of users. It brings together computer engineering (through building and use of biomedical sensors), software engineering and computer science (building and extending affective computing systems and machine learning classification) and psychology.

To complement the lab’s skills, Calvo collaborates with the rest of the Computer Engineering Group (van Schaik and Jin) and with psychologists at Faculty of Education (Reimann).

Dr Calvo has been on sabbatical in the United States since April (after teaching the first weeks of the semester). The aim is to read affective computing research and establish collaborations with experts overseas. So far, the trip has resulted in active collaboration with researchers at the University of California- Los Angeles, University of Southern California and University of Memphis.
Four students graduated in this period: Nick Carroll (PhD), Di Dong (MER), Sergio Freschi (MER), JingYu (Daniel) Zhang (MER).

**Research Funding**

Four grants are currently ongoing:

- Reimann, P; Calvo, RA and Yacef, K "Comprehensive support for collaborative writing: visualising argument, text and process structures". (2009-2012). Australian Research Council - Discovery Project $270,000
- Calvo, RA; Jones, J, Drury, H Airey, D and See, H "Writing for engineering disciplines: supporting the development of student writing across curricula" (2009). Teaching Improvement and Equipment Fund - University of Sydney $114,288
- Calvo, RA; Markauskaite, L; Tridgwell, K "Analysis of pedagogical designs, and their relationships with students’ learning experiences" (2009). Teaching Improvement and Equipment Fund - University of Sydney $9,660
- Reimann, P; Calvo RA and Paltridge B- "Using machine learning and automated document analysis methods to support english composition training" (2006-2008). Australian Research Council - Discovery Project $200,000.

**Research Facilities**

- Affective and Brain Computer Interfaces room, where we keep specialized biomedical sensors, computers, and facilities for working with subjects
- Servers for processing text collections and intensive data mining tasks.

**Research Collaboration**

- As above

**Professional Service**

- RAC is Senior Member of IEEE
- Reviewer for IEEE Trans on Learning Technologies and IEEE Trans Knowledge and Data Engineering

**Publications**

**Book Chapters:**


Journal Papers:

Conference Papers:
[9]. D Dong and RA Calvo, "Using component extraction association rules for sensor data", in Proceedings of Workshop on Advances and Issues in Biomedical Data Mining, Pacific-Asia Knowledge Discovery and Data Mining (PAKDD09), 27-30 April (Bangkok, Thailand), Springer-Verlag.
Fibre-optics and Photonics Laboratory

The Fibre-optics and Photonics Laboratory (FPL) specialises in research into advanced optical techniques for information systems. Principal areas of work focus on photonic signal processing, microwave photonics, optical communications, nonlinear fibre optics, optical network security and encryption, optically-controlled phased arrays, and terahertz/gigahertz photonics in communication and radar systems. The Fibre-optics and Photonics Laboratory also participates as a core partner in the Institute of Photonics and Optical Science.

Our research into photonic signal processing explores new, powerful paradigms for processing high bandwidth signals. This transcends the traditional function of photonics that has, until recently, focused on signal transmission, to open up new possibilities for directly processing the signals that are modulated on an optical carrier. The motivation arises from the potential of exploiting the unique, high time-bandwidth product capabilities of photonic signal processing to overcome the inherent bottlenecks caused by limited sampling speeds in conventional electrical signal processors. This approach also allows direct processing of high-frequency signals that are already in the optical domain, and has applications to radio over fibre, radar, defence, and radio astronomy arrays. The Fibre-optics and Photonics Laboratory is one of the leading research laboratories in the world in this field.

Our research into photonic generation, distribution and control of THz and millimetre wave signals studies new ways generating high frequency signals, and photonic technology for phased array antenna systems. This includes photonic techniques for frequency conversion of signals and for generating mm-wave and THz signals. This has applications to antenna remoting, and for imaging applications at terahertz frequencies, which has enormous potential for spectroscopic applications, allowing substances to be identified by their spectral signature ranging from security to medical to food sciences.

Our research activities in the fields of optical communications and nonlinear fibre optics, focus on four areas, namely wavelength division multiplexing in optical networks, dispersion managed solitons, optical network security and nonlinear pulse propagation in Bragg gratings and photonic crystals.

The Fibre-optics and Photonics Laboratory has been highly successful in winning major research funding from the Australian Research Council.
Personnel

Academic staff:
- Professor Robert Minasian, Professor and Director
- Associate Professor Javid Atai, Associate Professor
- Dr Xiaoke Yi, Lecturer.

Researchers and postgraduate students:
- Dr Erwin Chan, Senior Research Fellow
- Dr Weiwei Zhang, Research Fellow
- Mr Saul Carrol, Postgraduate student
- Mr Tong Chen, Postgraduate student
- Mr Stephen Hanham, Postgraduate student
- Mr Thomas Xian Hua Huang, Postgraduate student
- Ms Yazhuo Li, Postgraduate student
- Mr Daniel Neill, Postgraduate student
- Mr Cibby Pulikkaseril, Postgraduate student
- Mr Abrar Salim, Postgraduate student
- Mr Xudong Wang, Postgraduate Student.

Research Achievement and Activities
- We have demonstrated a record high Q microwave photonic filter bandpass filter that can operate without the limitations of coherence interference and of phase induced intensity noise. It is based on our pioneering concept of a frequency-shifting recirculating delay line, which can simultaneously achieve a multi-tap, high-Q filter and a very large suppression of noise, while also enabling the use of a conventional narrow linewidth laser source without suffering from coherent interference effects.

- A new microwave photonic filter structure realizing fully programmable RF filtering that can tune the filter centre frequency and also reconfigure the filter shape, while exhibiting multiple taps and bipolar taps, has been obtained. It is based on a new arbitrary spectrum slicing technique using a multi-port programmable wavelength processor, based on liquid crystal on silicon pixels, which offers programmable FIR filtering using software control. Experimental results have demonstrated a high-order microwave filter with tunability, reconfigurability and bipolar taps.

- A new structure that can realise widely tunable microwave photonic notch filtering, high free spectral range, and coherence-free operation simultaneously has been developed. It is based on a Sagnac loop interferometer that comprises an off-loop-centre electro-absorption modulator, and a wavelength dependent delay element. Experimental results have demonstrated both continuous and discrete widely tunable notch filters, high frequency and high free spectral range, and coherence-free low-noise operation with very deep notches in excess of 40 dB.

- A new microwave photonic filter that solves the problem of realizing a single bandpass RF response has been obtained. The filter is based on using phase modulation together with a pair of gratings, and eliminates the baseband response and periodic spectral response of
typical FIR filters. Experimental results demonstrate a single passband square-type bandpass filter response, and operation to high frequencies.

- The phase induced intensity noise generated by the high resolution delay line signal processors has been analysed. Investigations on using the delayed differential technique for phase noise reduction in various delay line signal processors have been completed. Results showed that the delayed differential structure can largely suppress the phase noise at the passband of a high resolution delay line bandpass filter. It was found that the large phase noise suppression results in a significant signal to noise ratio improvement in the delay line bandpass filter.

- A new microwave photonic filter that realizes programmable complex coefficients with multi-taps in the optical domain has been developed. It is based on a new optical RF phase shifter achieved by using a programmable wavelength processor (PWP). It manipulates the amplitude and phase of optical spectral components, which enables the integration of single sideband modulation and the generation of arbitrary phase shift of the complex coefficients within one device. Experimental results demonstrate tunable multi-tap RF filters with wideband tuning range over the full free spectral range by software programming the complex coefficients.

- A new structure for realising an equivalent multi-tap bandpass filter based on a single wavelength modulation technique, has been obtained. It is based on intensity modulating a continuous wave light multiple times, and has the ability to generate many taps to increase the filter resolution. It also enables windowing to be employed to enhance the filter rejection ratio. Experimental results have been obtained that demonstrate a multiple-tap bandpass filter with high rejection ratio and with no coherence and phase-induced intensity noise limitations.

- We have characterized the collisions of dispersion managed solitons in a multi-channel stabilized link. It is found that the outcome of the collisions may be either an elastic collision, a merger or destruction of both solitons, depending upon their initial temporal separation and the value of inverse-group-velocity parameter.

- The existence and stability of gap solitons in a model of hollow core fibre in the normal zero and anomalous dispersion regimes have been analyzed. It is found that gap solitons in the normal dispersion regime are more stable than those in the anomalous and zero dispersion regimes. This work has applications in novel nonlinear optical devices e.g. optical buffers.

- We have experimentally investigated the limits of intrusion detection systems in a gigabit optical network. It is found that both the location of the tap along the link and the amount of light tapped from the optical link are important for successful recovery of the data. In particular, we have shown that, under certain circumstances, an optical network equipped with an Intrusion Detection System may be tapped without being detected.

- A dielectric rod antenna operating at 600GHz for terahertz applications has been designed and implemented as a possible focal plane array element. The tapered dielectric rod antenna was fabricated using laser ablation. A ring slot was used as it allows easy integration of a diode detector with high efficiency and measured radiation patterns for an antenna element have been obtained.
• A new photonic technique/ based upon optical heterodyning for the generation of microwave and millimetre wave signals, has been demonstrated. Coherence control of a comb of time-delayed and frequency-shifted optical signals is used to selectively beat multiple optical signals together to produce a stable, spectrally pure microwave or millimetre wave signal. This approach is demonstrated by generating signals at 11.25 GHz and 30 GHz. The linewidth of the generated signal is independent of the linewidth of the optical source employed and is shown to be less than 100 Hz.

Research Funding
• Professor Robert Minasian, “New paradigms for high-resolution microwave photonic signal processing”, ARC Discovery grant, $965k, 2009-2013
• Professor Robert Minasian and Dr Erwin Chan, “Dynamically tunable, low noise, discrete time optical processing of high speed signals”, ARC Discovery grant, $400k, 2007-2009
• Dr Xiaoke Yi, "Novel coherence-free microwave photonic signal processors", ARC Discovery grant, $155k, 2009-2011
• A/Professor Javid Atai, "A novel optical network security and encryption device", ARC Linkage grant, $99k, 2006-2009
• Professor Robert Minasian, “Novel coherence-free photonic microwave signal processors”, ARC Discovery grant, $500k, 2006-2008
• Dr Xiaoke Yi, “New spectrum-sliced photonic signal processors for high frequency signal processing”, Early Career Researcher Grant, University of Sydney, $20k, 2009

Research Facilities
• FPL has state-of-the-art experimental research facilities, which are unique in Australia, in microwave photonics research equipment
• The research resources of FPL include comprehensive photonics laboratories, laser and fibre-optics laboratories, and experimental capabilities for high speed optical and microwave measurements of signals.

Research Collaboration
• Research collaboration with CSIRO ICT Centre on THz imaging and phased array techniques
• Research collaboration with Tel Aviv University, Israel; and University of Aberdeen, UK
• Collaboration with Centre for Ultrahigh bandwidth Devices for Optical Systems, The University of Sydney
• Collaboration with the University of New South Wales
• Tenix Pty Ltd.

Awards
• Professor Robert Minasian has been elected a Fellow of the Optical Society of America by the Board of Directors. The citation is for contributions to the fundamental understanding of photonic signal processing of microwave signals
• Dr Erwin Chan was awarded the Australian Postdoctoral Fellowship by the Australian Research Council

• Professor Robert Minasian was awarded an Optical Society of America OSA Fellow Travel Grant from the International Council of OSA to encourage global interaction and has presented lectures to foster optics and photonics activities around the world.

Professional Service

Robert Minasian:
• Fellow IEEE
• Fellow OSA Optical Society of America
• Fellow IEAust Engineers Australia
• Associate Director, Institute of Photonics and Optical Sciences
• Associate Editor of Optical Fiber Technology
• Member, Editorial Board of the IEEE Transactions on Microwave Theory and Techniques
• Member, IEEE Technical Committee on Microwave Photonics of the IEEE Microwave Theory & Techniques Society (IEEE MTT-S)
• Assessor for Australian Research Council
• Member, International Advisory Committee for the Asia-Pacific Microwave Photonics Conference (AP-MP)
• Member, Technical Program Committee of the IEEE International Meeting on Microwave Photonics, MWP2009 and MWP2008
• Member, Technical Program Committee of the Asia-Pacific Microwave Photonics Conference (APMP2009)
• Session Chair at MWP2008 and APMP2009
• Invited presentation at NICT National Institute of Information and Communications Technology, Tokyo Japan, 2009
• Invited presentation at Kyoto University, Japan, 2009

Javid Atai:
• Member OSA Optical Society of America
• Senior Member IEEE
• Assessor for Australian Research Council
• Consultant for Australian Institute of Higher Education Pty.

Xiaoke Yi:
• Member IEEE
• Member, Technical Program Committee of the International Conference on Advanced Infocomm Technology (ICAIT), 2009
- Session Chair at OECC2009

**Erwin Chan:**
- Member, Technical Program Committee of the OSA Conference on Lasers and Electro-Optics (CLEO)

**Publications (2008-)**

**Book Chapter:**

**Journal Papers:**


Conference Papers:


Patent:

Centre of Excellence in Power Engineering

The Centre is active in many areas of power engineering. In particular, the Centre conducts research in power electronics, inverters and control, selective harmonic elimination pulse-width modulation control, voltage-source converter based FACTS and HVDC systems, advanced power transmission technologies, intelligent grid infrastructure, power systems, monitoring and diagnostics technologies for power system infrastructure, utility asset management, harmonics, distribution and transmission systems and power electronics applications, renewable energy systems, wind energy, solar energy, grid-connected inverter technology, AC and DC microgrids, fuel cell systems, energy efficiency, sustainable energy solutions and systems, random PWM techniques, motor drives, power quality, sensorless control of motors, synthesis, modelling and analysis of power electronics circuits, control for power electronics systems, computer-aided-design of circuits, soft-switching techniques, power factor correction, sensing technologies, dynamical systems and control, systems theory, robust control, neural networks, adaptive control of electric machines, real-time control with micro controllers.

Personnel

Academic staff:

- Professor Vassilios G Agelidis, EnergyAustralia Chair of Power Engineering, Director
- Dr Yash Shrivastava, Senior Lecturer, Deputy Director
- Dr Swamidoss Sathiakumar, Senior Lecturer
- Dr Dylan Lu, Lecturer.

Researchers and postgraduate students:

- Dr Marcos Garcia Arregui, Postdoctoral Fellow
- Mr Mahdi Alsaffy, MPhil
- Mr Nikolas Flourentzou, PhD
- Mr Corby Fu, ME Research
- Mr Boyang Hu, MPhil Research
- Mr Narayanaswamy Iyer, PhD
- Mr Shu Kong Tom Ki, PhD
- Mr Georgios Konstantinou, PhD
- Mr Ian David Laird, PhD
- Mr Jaebok (James) Lee, ME Research
Visitors:
- Dr Mohamed SA Dahidah, the University of Nottingham, Malaysia Campus.

Research Achievement and Activities
The most significant achievement of the power engineering group is its elevation to a University Research Centre of Excellence on 23 April 2009 by the Provost, Professor Don Nutbeam. The name is Centre of Excellence in Power Engineering and has been approved for an initial period of five years.

Research Funding
- Research Bridging Support Funding 2008, the University of Sydney: $50,000. Project Title: “Multi-terminal direct current distribution system based on proton exchange membrane fuel cells”
- ABB AB Corporate Research Centre, Sweden
- ARC Discovery Project 2009-2011, DP0985867, $175k, Hot-swappable and high-efficient grid-connected power electronics system for photovoltaic modules with direct power transfer technique, with Dr DDC Lu
- ARC Discovery Project 2008-2010, DP0877588, $150k, Theoretical study and experimental verification of low cost, integrated and efficient AC/DC power supplies using time-multiplexing control, Dr DDC Lu
- ARC Linkage Grant Project, 2009-2012, LP0991663, $660k, An intelligent integrated energy communication system, with Professor B Vucetic and Dr Y Li. Collaborating organisation: EnergyAustralia.

Research Facilities
The Centre has recently moved to the new power engineering space incorporating:
- The Sir William Tyree Laboratory in Power Engineering
- ABB Technology Centre
- TECHLAND™ Studios
- Auditorium
- Boardroom
- Academic offices
- Research personnel offices
- Hospitality suite.

The Centre also has access to a research laboratory in Level 4.
Research Collaboration
- Malaysia, The University of Nottingham, Malaysia Campus
- Denmark, Aalborg University
- Seoul National University of Technology, South Korea.

Awards
- In 2009, Dylan Lu was elevated to Senior Member by the IEEE.

Professional Service

Vassilios Agelidis:
- CSIRO Alternative Energy Review Panel Member, 2009
- IEEE 39th PESC 2008, Rhodes, Greece, Technical Chair
- IEEE PELS Administrative Committee Member-at-Large 2007-2009
- ARC Intreader ARC Discovery 2009, 2010
- AUPEC 2008 Organising Committee Member
- VESTAS Visiting Research Professor at Aalborg University, Denmark 2008-09
- Universiti Tenaga Nasional, Kuala Lumpur, Malaysia, External Advisor, 2008-10
- University of Malaya, Kuala Lumpur, Malaysia, External Advisor, 2008-11
- Editorial Board Member: International Journal of Renewable Energy Technology (since May 2008)


Presentations:
- “Intelligent power electronic grid interfaces”, Royal Sydney Yacht Squadron, invited presentation for the Warren Centre for Advanced Engineering, 18 July 2008
- “Nuclear education”, Engineers Australia Harricks Auditorium, Chatswood, NSW, 26 November 2008

Dylan Lu:
- IEEE 39th PESC 2008 Technical Committee Member and Session Chair
- AUPEC 2008 Organizing Committee Member
- Editorial Panel Member of the Australian Journal of Electrical and Electronics Engineering (AJEEE)
• ARC International Reader ARC Discovery 2010
• Reviewer of IEEE Transactions on Power Electronics, IEEE Transactions on Industrial Electronics, IEEE Transactions on Circuits and Systems-I, and major IEEE conferences on power electronics and drives.

Publications

Journal Papers:


Conference Papers:


Telecommunications Laboratory

The Telecommunication Laboratory specializes in a broad area of wireless communication systems, including transmission, error control coding, adaptive signal processing, protocols, routing, network architectures, network security, location estimation and network traffic modelling. It consists of Wireless Engineering group led by B Vucetic and Wireless Networking Group (WiNG), led by A Jamalipour.

The research outcomes have wide applications in satellite, cellular, ad hoc, sensor and wireless local area networks. The laboratory is engaged in both fundamental and applied research. The activities are focused on providing research support to the telecommunications industry. Examples of recent achievements include design of novel space-time turbo codes, soft encoding for cooperative turbo codes, cooperative interference cancellation in WLANs and cellular networks, adaptive space-time coding, combined network and channel coding. A wide range of research projects have been undertaken in cooperation with industry.

The Wireless Networking Group (WiNG) at the School of Electrical and Information Engineering, University of Sydney pursues advanced research and development for individual networks and their integration toward a collaborated heterogeneous architecture. We work on the architecture design and related protocols and techniques to make the future mobile broadband Internet closer. We also work on securing the information network and bringing both infrastructure-based networks (e.g. cellular mobile, wireless LAN, and WiMax) and infrastructure-less networks (e.g. ad hoc and sensor networks) into a mutual agreement and collaboration. Our research applies into mobile terrestrial and satellite communications. WiNG realizes the importance of international collaborations and visibility. In that context, we carry out several of our research projects through international collaborations with academia and industry in Asia, Europe, and North America and we always welcome new partners from overseas.

At present, the Laboratory has a number of research activities in cellular communication systems, sensor and ad hoc networks with applications in smart grids and environment monitoring. It has been successful in attracting considerable funding from Australian Research Council as Discovery and Linkage grants and developing close collaboration links with international universities and institutes.
Currently there are more than twenty postgraduate research students at the Telecommunications Laboratory, supported by scholarships from various government and industry sources.

**Personnel**

**Academic staff:**

- Professor Branka Vucetic, Head of School
- Dr Abbas Jamalipour
- Dr Guoqiang Mao
- Dr Yonghui Li.

**Postgraduate Students**

- Mr Raed Manna, PhD Student
- Mr Seh Chun Ng, PhD Student
- Mr MD Shahriar Rahman, PhD Student
- Mr Siavash Bayat, PhD Student
- Ms Neda Aboutorab, PhD Student
- Mr Xiaooyuan Ta, PhD Student
- Mr Kun Pang, PhD Student
- Mr Vladislav Obrenovic, MPhil Student
- Mr Raymond Louie, PhD Student
- Mr Xinyi Li, MPhil Student
- Mrs Anushiya Kannan, PhD Student
- Mr Fan Bai, PhD Student
- Mr Fazirulhishyam Hashim, PhD Student
- Mr Farshad Javadi, PhD Student
- Yaozhou Ma, PhD Student
- Niloofar Ebrahimi, PhD Student
- Mu Qi, PhD Student
- Tadeusz Wysocki, PhD Student
- Nejla Ghaboosi, PhD Student
- Srdjan Vukadinovic, PhD Student
- Zijie Zhang, MPhil Student
- Ruoxuan Qi, MPhil Student
- Bin Guo, MPhil Student
- Ms Lei Lei Wu, MPhil Student
- Mr Wen Song, ME(Research) Student
- Mr Di Zhang, ME(Research) Student
- Mr Chi Zhang, ME(Research) Student
- Mr Jie He, ME(Research) Student
- Mr Qidan Feng, ME(Research) Student
- Mr Jesudass Arockiasamy, ME(Research) Student.
Research Staff

- Dr. Van Dong Pham, Professional Officer
- Dr. Zhendong Zhou, Research Fellow
- Dr. Zhihui Lin, Research Fellow
- Dr. Kumudu Munasinghe, Research Fellow
- Dr. Wibowo Hardjawana, Research Fellow

Research Achievement and Activities

- **WiMAX System Evaluation in Real Propagation Environment**

As the demand for high-speed wireless broadband services rapidly increases, the IEEE 802.16 standard defines a wireless broadband access technology called WiMAX. The specifications for medium access control (MAC) and physical (PHY) layers are defined in the standard. A critical part of the MAC layer specification is packet scheduling, which resolves the bandwidth allocation and service order of the subscriber stations. Although the 802.16 standard suggests the main principles in designing QoS architecture to support different types of broadband services, scheduling algorithms for uplink and downlink traffics are left to researchers and manufacturers to design and implement. While there have been many studies on design and evaluation of different scheduling algorithms in WiMAX networks, there are not too many comprehensive studies for evaluation and comparison of different scheduling algorithms in WiMAX networks. Furthermore, the channel propagation models used in the simulations are too simplistic or optimized, which may drop the credibility of the research study. Evaluating the performance of scheduling algorithms under a realistic channel condition thus becomes one of the most important tasks in the realization of large scale WiMAX networks. This project aims to conduct a comprehensive performance study in point to multipoint, OFDM-based WiMAX networks under a unified platform, with a high-accuracy channel propagation model based on the ray tracing technique, which is able to produce a site-specific channel prediction. A number of representative scheduling algorithms is modified and implemented in NS2 for this study, and performances are evaluated in terms of system throughput, ability to meet QoS requirements for each type of service and fairness to different service classes.

- **Spectrally Efficient Cooperative Precoding and Beamforming for Multi-User MIMO Systems**

The spectral efficiency in existing cellular mobile networks, WiMAX and WLANs (Wireless Local Area Network) is limited by interference. In cellular mobile networks or WiMAX, the dominant interference comes from adjacent cells, while in co-working WLANs, the interference from other networks, operating in the same area, is a major limiting factor. We propose to get the Base Stations in cellular mobile networks or WLANs to cooperate with each other and transmit in the same frequency band and the same time slots. In the cooperative transmission scheme proposed here, multiple base stations (BSs) share information about the transmitted messages to their respective users and wireless channels via a backbone network. Individual BSs are equipped with multiple transmit antennas. Each BS transmitter uses the information of the transmitted signals from other BSs and wireless channel condition to precode its own signal. The precoded signal for each BS is broadcast through all BS transmit antennas in the same frequency band at a given time slot. The precoding operation and transmit-receive antenna coefficients are
chosen in such a way as to minimize the interference coming from other BS transmissions. The Tomlinson Harashima precoding (THP) cancels part of the interference while the transmit-receive antenna weights, designed by using the Zero Forcing and Duality theorem, cancel the remaining interference. The calculated receive antenna coefficients are then sent from the transmitter to the receiver through the wireless channel prior to the data transmission. The simulation results show that the proposed scheme significantly outperforms existing cooperative transmission schemes in terms of the SER performance and complexity and approaches an interference free performance under the same configuration. An interference free performance is defined as the performance of a single user transmission when all BSs cooperate.

- **Distributed Network Channel Coding for Wireless Sensor Networks**

  Wireless sensor networks (WSN) has attracted a lot of attention recently. A WSN usually contains a large number of low-cost and low-power wireless sensor nodes, some aggregated nodes, and some destination nodes. There are many potential applications of sensor networks, such as surveillance and monitoring, tracking and location. In these applications, the sensor nodes are usually cooperated with each other in a multi-hop fashion. In this project, we consider the problem of multicasting data packets from multiple source groups of sensor nodes to multiple destinations via a common wireless relay network. We refer to such a channel as a multiple access relay interference channel (MARIC), as multiple groups of source nodes interfere with each other at each destination. In this project, we will develop a robust distributed network and channel coding scheme for MARIC.

- **Iterative Channel Estimation for High Mobility MIMO-OFDM Systems**

  Multiple-input multiple-output and orthogonal frequency division multiplexing (MIMO-OFDM) techniques have been adopted in 3GPP LTE and WiMAX standards to achieve very high data rates (> 10Mbps). In these standards, high mobility users, moving at speeds higher than 300Km/h, need to be supported. Accurate channel state information (CSI) is required for reliable signal detection at the receiver. Pilot symbols are inserted among sub-carriers before transmission to accurately estimate the wireless channel. In a high mobility environment, the wireless channel is time-variant and frequency-selective causing the symbol transmission to be impaired by the Doppler spread. The Doppler spread destroys the orthogonality and creates inter-carrier interference (ICI) between OFDM sub-carriers. In addition, the channel changes significantly within one OFDM symbol. As a consequence, the Standard channel estimation methods cannot be used in 3GPP LTE and WiMAX to support high mobility users. We propose a novel pilot-aided iterative receiver, based on pilot symbols and iterative soft-estimate of data symbols. The channel is estimated by time-domain interpolation and least-square (LS) methods. Soft-estimates for data symbols are obtained by a maximum-a-posteriori (MAP) decoder and improved subsequently. The simulation results show that the performance of the proposed iterative receiver outperforms the existing schemes. The performance degradation of the proposed receiver structure when users move at speed of up to 324Km/h compared to the performance of a perfect CSI system with a zero Doppler shift is shown to be very marginal.

- **Interference Cancellation in Multi-user Multi-hop MIMO wireless networks by Using Precoding and Beamforming**
The next generation of wireless mobile networks is expected to provide multimedia applications with a high quality of service and broadband access. Even with the advanced signal processing techniques employed in such networks (e.g., OFDMA and MIMO), the resulting SNR is still not sufficient to support the requested data rate at the cell edge. Competition with wire-line networks requires that wireless networks be highly reliable and also fill coverage for maximum mobility. These challenges are conflicting at a basic level; because increasing data rate reduces reliability, and increasing minimum reliability of the service reduces the coverage area. The most widely used strategy to address these challenges is to shrink the size of the cell, effectively increasing the number of base stations over a given area. Although this strategy will increase the capacity because users are much closer to their serving base stations (unless the increased interference outweighs the increased signal power), its benefit is limited because of the exceeding cost of base stations and radio frequencies. Instead, an increasingly attractive strategy is to insert relays into the cell that transmit in the same frequency band and whose purpose is to aid communication from base station to mobile stations and vice versa. Relaying techniques have emerged as a powerful approach to improve the coverage, capacity and reliability of wireless networks. In this project, we are going to consider multi-user multi-hop MIMO wireless networks. In our scenario several base stations, each with multiple antennas, will cooperate to send the data in the same frequency band and time slot to several users (mobile stations), each with multiple antennas, in a wireless cellular network thorough multi-hop relaying. The relay is equipped with multiple antennas and the objective of the project is to design an efficient cooperative downlink transmission scheme employing precoding and beamforming that eliminates the interference and increases the capacity and coverage of the network.

- Interference cancellation in cognitive networks
Cognitive radio has been recently proposed as a promising technology to improve the spectrum utilization by allowing unlicensed users to coexist in licensed bands. However, the interference caused by sharing the same radio channel becomes an obstacle that limits the system performance, such as the system throughput. Most of the research is currently focusing on the interference cancellation in single hop cognitive radio. However, not much work has been done on the interference cancellation for the multi-hop cognitive radio network case. The aim of this project is to design an efficient interference cancellation scheme in a multi-hop cognitive network, and analyze its performance. It is assumed that the CR network is equipped with multi-antennas so that it can deploy precoding and/or power control to effectively balance between avoiding the interferences at the PR terminals and maximizing the throughput of the CR link. Some possible methods for interference cancellation and pre-coding that can be applied in such a scenario are zero-forcing and minimum mean square error (MMSE). These schemes are going to be applied for different structures of the multi-hop cognitive radio networks and under different assumptions and their performance will be studied and evaluated.

- Game Theory Based Transmission Strategies for Cognitive Radio
It has been recognized by radio regulatory bodies that the exclusive use of spectrum to licensed users is highly efficient. This is due to the high variability of traffic statistics over time, space and frequency, which means that often, a significant proportion of spectrum is unused. Cognitive radios offer a possible solution, whereby these radio nodes are allowed to transmit when the licensed users are not transmitting. This has the potential to lead to a high efficient use of the
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spectrum. However, there remain a number of potential problems which need to be overcome before cognitive radios are viable. One of the more significant problems is the design of transmission strategies between cognitive radio nodes without causing significant interference to the licensed users. In this project, we address this issue by utilizing tools from game theory. In particular, we will design transmission strategies for transmitter-receiver cognitive radio pairs, which communicate with each other whilst causing acceptable levels of interference to the licensed users. We first consider non-cooperative scenarios, where the cognitive radios choose transmission strategies without any consideration of the other cognitive radio users. We will derive the optimal stable operating point, or Nash equilibria, for this scenario. We also consider cooperative scenarios, where the cognitive radios may interact with each other to choose their transmission strategies.

- **Wireless Smart Metering Systems**
  The Smart Metering System aims to replace expensive traditional manual methods of gathering meter data by using a wireless, automatic meter reading (AMR) system for saving energy and lessening billing costs. Via Zigbee and WiMax networks, the system is designed to provide services comprising bill collection, utility consumption monitoring, etc. to help service distributors to save on billing costs and implement Real-time Monitoring and Distribution Control.

- **Cooperative Beamforming in MIMO Relay Broadcast Channels**
  Wireless multiuser communications are suffering from problems of reliability, coverage and spectrum efficiency. Relay broadcast is one of the promising techniques to solve these problems by exploiting both the distributed spatial diversity arising from the relay mechanism and the local spatial diversity introduced by the multiple antennas. Studies on the channel capacity of relay broadcast channels have shown a significant improvement over the classical broadcast channels. A practical design of transmission scheme is yet to be invented. In this project, we design a low-complexity beamforming, relaying and combining scheme for MIMO relay broadcast channels. We consider the scenario where one base station (BS) transmits to two mobile stations (MSs), where one of the MSs with strong signal reception and/or processing power can help the other besides receiving its own data. The transmission vector space is partitioned into subspaces to accommodate the transmission from the BS to both MSs and the relaying between MSs. The zero forcing (ZF) criterion is used to avoid interferences among these transmissions. With multiple antennas at both the BS and MSs, and the channel state information (CSI) available (fully or partially) to the relevant parties, the subspace partitioning can be adjusted to optimise the overall system performance. The optimal transmit power allocation between users and relay will be designed to improve the performance further. When more than two MSs are involved in the communication scenario, a relay selection algorithm will be developed in such a way the most effective MS is selected to act as the relay.

- **A Graph Theoretic Approach to Fundamental Problems in Wireless Networks**
  Wireless ad-hoc and sensor networks have been widely used in military and civilian applications. Despite significant research in these areas, there remain a large number of fundamental research problems to be investigated. Graph theory has been increasingly used to study these problems, which include but are not limited to graphical properties of wireless ad-hoc and
sensor networks to ensure unique localization of wireless nodes and efficient localization algorithms; statistical characterization of multi-hop wireless networks and its application; geometric constraints among connected nodes and their use in parameter estimation without manual calibration. Research into these fundamental problems will benefit almost all areas in wireless ad-hoc and sensor networks, including wireless network routing, scheduling, dimensioning, interference control, energy management and localization.

- **Graph Theoretic Analysis of Connectivity Properties in Static and Dynamic Wireless Multi-Hop Networks**

  Wireless multi-hop networks, in various forms e.g. wireless mesh networks, opportunistic networks, delay tolerant networks, mobile ad-hoc networks, vehicular ad-hoc networks and wireless sensor networks, are being increasingly used in military and civilian applications. In multi-hop networks, wireless devices are self-organized to create a network by exploiting their wireless interfaces and packets are forwarded hop-by-hop by the wireless nodes collaboratively from the source to the destination. Advanced applications of wireless multi-hop networks demand better understanding on the fundamental properties of these networks.

  Connectivity is the most fundamental property of wireless multi-hop networks. A network is said to be connected if there is a path between any pair of nodes in the network. A network is connected if there are mutually independent paths between any pair of nodes in the network. Most network functions, e.g. routing, scheduling and topology control, rely on the underlying network to be connected. Some functions, e.g. cooperative communication, robust localisation and reliable packet delivery, require the network to be connected. This research will investigate various aspects of the connectivity properties of static and dynamic wireless multi-hop networks, e.g. the occurrence of a giant component, the probability that two nodes are separated by h-hops, the maximum number of hops, the transmission power required to ensure a high percentage of nodes in the network is connected or k-connected and the associated network performance and protocols.

  The research outcomes will provide answers to a number of important and yet-to-be-completed problems on network connectivity and will pave the way for a complete understanding on the connectivity properties of static and dynamic networks. The research outcomes will benefit many other research areas and boost research in these areas.

- **Wireless Sensor Network Localization and Its Applications**

  Wireless sensor networks are a significant technology attracting considerable research attention in recent years. It is one of the most important technologies for the 21st century. Recent advances in wireless communications and electronics have enabled the development of low-cost, low-power and multi-functional sensor nodes that are small in size and communicate in short distances. These tiny sensor nodes, which consist of sensing, data processing, and communicating components, bring the idea of wireless sensor networks into reality. Sensor networks represent a significant improvement over traditional sensors. Cheap, smart sensors, networked through wireless links and deployed in large numbers, provide unprecedented opportunities for monitoring and controlling homes, cities and the environment. In addition,
networked sensors have a broad spectrum of applications in the defense area, generating new capabilities for reconnaissance and surveillance as well as other tactical applications.

Emerging applications for wireless sensor networks will depend on automatic and accurate location of thousands of sensors. In environmental sensing applications such as bush-fire surveillance, water quality monitoring, precision agriculture and indoor air quality monitoring, “sensing data without knowing the sensor location is meaningless”. In addition, location estimation may enable applications such as inventory management, intrusion detection, traffic monitoring and telecare. In this research we shall investigate distributed location estimation algorithms in wireless sensor networks and its applications.

List of Research Topics at the Wireless Networking Group (WiNG)

- Data Aggregation Techniques in Wireless Sensor Networks
- Intermittently Connected Mobile Ad Hoc Networks
- Multi-layer and Cognitive Wireless Mesh Networks
- Inter-Vehicular Communication Networks
- Cross-correlated Security and QoS in Heterogeneous Mobile Networks
- MAC Framework for Cognitive Radio Networks
- Cooperative Cellular Networks
- Cognitive Mobile Networks.

Research Funding

- Yonghui Li, "Efficient distributed coding in wireless networks", ARC Discovery Project, $200,000, 2009-2011
- Yonghui Li, CSIRO OCE PhD Scholarship, "Cognitive radio techniques in multi-hop wireless broadband services", $75,000, 2009-2012
- Zhendong Zhou, “Cooperative relay broadcast techniques and their applications in wireless broadband communications,” The University of Sydney Bridging Support Grant, $20,000 (2009)
- Prof Branka Vucetic, Dr Yonghui Li and Dr Mischa Dohler, Dynamic spectrum access in multi-hop wireless broadband networks, ARC Discovery grant, Period: 2008-2012
- Bjorn Landfeldt and Guoqiang Mao, “A graph theoretical approach to cooperative radio resource management”, The University of Sydney Bridging Support Grant, $50,000 (2008)
- Brian DO Anderson, C Yu and Guoqiang Mao, “Large scale complex multiagent systems: control methodologies and information architectures”, ARC Discovery Project, $661,000 (2008-2010)
- B Vucetic V Oklobdzija and X Tao, “Design and implementation of ultra-low power cooperative communication terminals”, ARC Discovery Grant, 2007-2009, $300,000
• ARC Australian Communications Research Network (ACORN), Period: 2004-2009, Researchers: Prof Branka Vucetic, Dr Abbas Jamalipour and Dr Iain Collings from Sydney University, Administering Institution: University of South Australia, Total Amount: $1,500,000
• Abbas Jamalipour, “Cross-correlated security and service quality in heterogeneous mobile communication networks”, ARC Discovery Project, 2007-2009, $303,810
• ARC Research Network for a Secure Australia (RNSA), Total fund received: $1,950,000, Administering Institution: University of Canberra, Researcher from Sydney University: Dr Abbas Jamalipour
• Abbas Jamalipour, “Pervasive data dissemination framework using intermittently connected mobile ad hoc networks for emergency, medical, and rural applications”, ARC Discovery Project, $270,000, 2009-2011.

Research Facilities
• Telecommunication Laboratory, in collaboration with UNSW and UTS telecommunications research groups, attracted an ARC LIEF grant in 2007 which was used to purchase an advanced WiMAX wireless communication system and reference design platform
• A smart metering WiMAX/Zigbee wireless network and a GPRS wireless sensor network for environment monitoring have been designed and implemented
• The Laboratory has access to high performance computing facilities, SUN workstations, Sun Enterprise server, and several other Unix machines
• The Lab is equipped with various test and hardware design tools, including Xilinx FPGA and TI DSP development tools, OrCAD, the Tanner IC design tools and simulation software such as Matlab, Mathematica, OpNet and Mume.

Research Collaboration
It has established close links with industry through Linkage and directly funded projects, most notably with Optus, Energy Australia and NEC.

There has been a program of research collaboration, staff and student exchange with international institutions, such as Tokyo Institute of Technology, HongKong Polytech University, Chinese Academy of Science, Beihang University, Siegen University, Westminster University, King’s College, CTTC, Southampton University, Federal University of Santa Catarina.

Awards
• B Vucetic received in 2008 a Telenor Best Telecommunications Paper Award
• B Vucetic was appointed as a Visiting Professor at Beihang University in 2008
• B Vucetic was appointed a Visiting Professor at Chinese academy of Science in 2009
• In 2008, Yonghui Li was awarded the QEII Research Fellowship by the Australian Research Council
• In 2009, Yonghui Li was elevated to Senior Member by the IEEE
• Mr K Pang was awarded School best tutor award.
Professional Service

Branka Vucetic:
- Appointed by the Australian Research Council as an Expert in the ARC College of Mathematics, Information and Communication Science for the period 2009-2011
- Served in 2008 as an External Assessor for the Hong Kong Research Grant Council and City University Hong Kong Research Committee
- Past Workshop Organizer for the PIMRC’08 conference
- Prof Vucetic and Dr Y Li finalized the editorial process for the EURASIP Journal on Wireless Communications and Networking, Special Issue on “Advances in Error Control Techniques”.

Yonghui Li:
- Was one of the organizers of the ACoRN Workshop on Co-operative Wireless Communications, held in Melbourne in July 2008 and is planning the next workshop in July 2009
- Dr Y Li and Prof Vucetic finalized the editorial process for the EURASIP Journal on Wireless Communications and Networking, Special Issue on “Advances in Error Control Techniques”.

Abbas Jamalipour:
- IEEE Communications Society, Education Board Member (2008-09)
- The General Chair, for the IEEE WCNC 2010
- Has been the Editor-in-Chief, IEEE Wireless Communications, 2006-2008
- Chair of Communications Switching and Routing Technical Committee, IEEE Communications Society 2009-2011
- TPC Chair, for the IEEE ICC 2011.

Publications (2008 -)

Books

Chapters in Books:


Journal Papers:


Conference Papers:


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