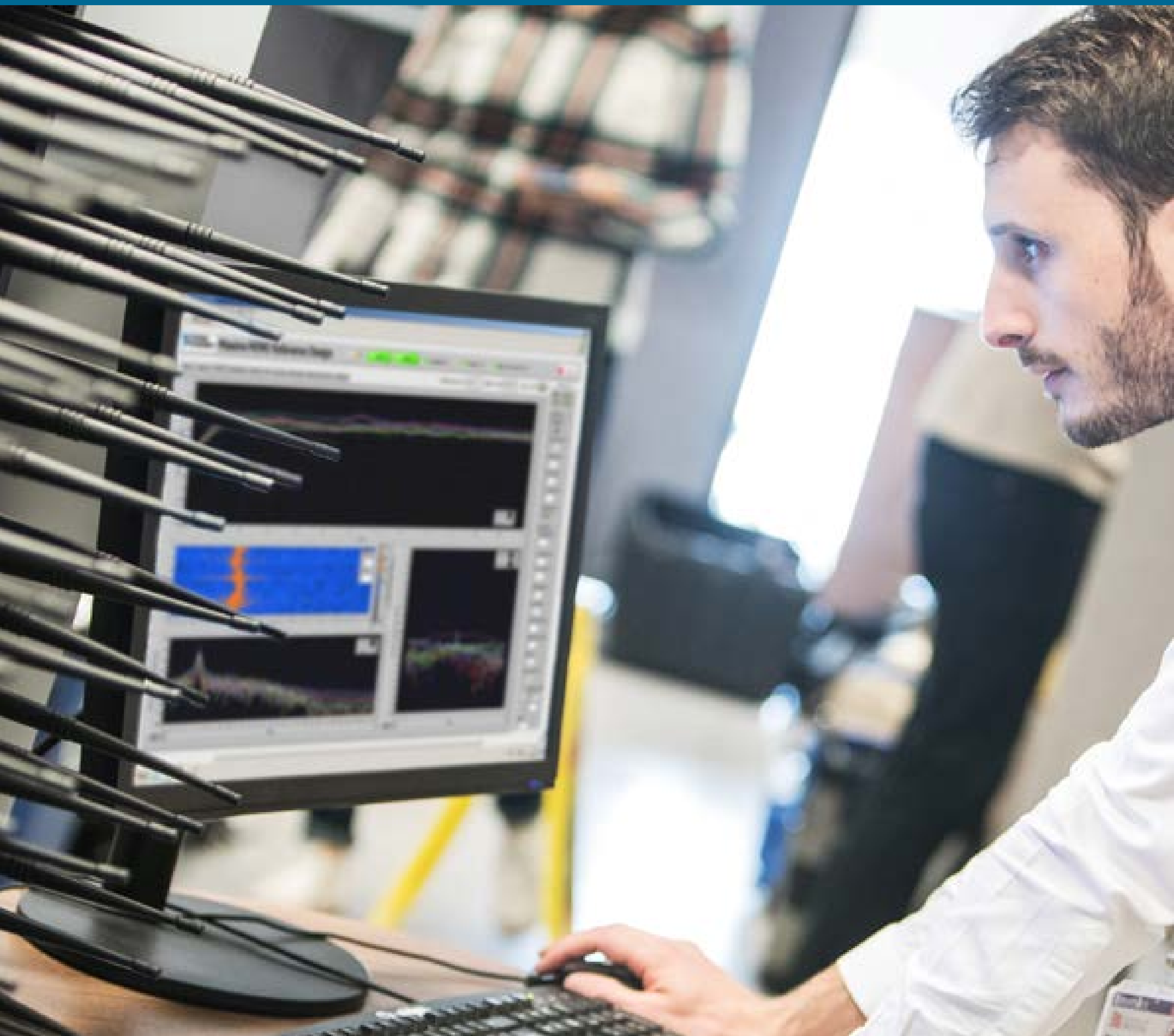
University of BRISTOL

EPSRC Engineering and Physical Sciences Research Council

EPSRC Centre for Doctoral Training in Communications

Annual Report 2018-19



Foreword

It is with great pleasure that we bring to you the latest report on the EPSRC Centre for Doctoral Training in Communications.

We have, since the launch of the CDT in 2011, recruited 9 cohorts of students. We are very proud of their achievements over this period in terms of innovation, publications, exploitation of research, public engagement and transition to employment.

This year's report showcases a selection of our students' recent achievements which we hope you will find informative and interesting. It also provides some insight into exciting new developments at Bristol associated with the new Temple Quarter Enterprise Campus.

Please enjoy reading the report and do not hesitate to get in touch if you would like to learn more.

Professor David Bull
Director

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Recruitment

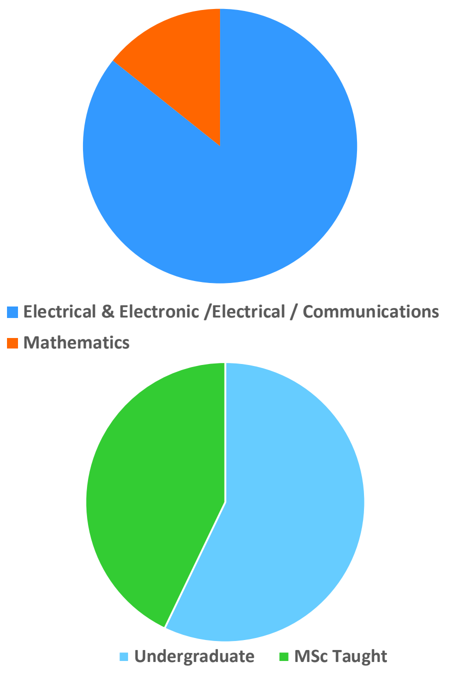
The Centre's mission is to produce graduates who are highly employable in either industry or academia - people who will become the future leaders in the sector.

In September we welcomed the latest cohort of Communications CDT students. Most are being funded by EPSRC together with additional funding from industry which enables us to recruit the very highest calibre students by offering enhanced stipends and opportunities. One student has been funded through a scholarship from his home country.

Students are attracted to the programme for many reasons including the opportunity to work with industry and secondments with companies in the UK and overseas. Several students are returning from industry to gain additional skills and expertise.

Bristol is a hub for IT and the digital industries, with companies providing opportunities for training and employment. In 2017 the city was named 'the best place to live in Britain' by The Sunday Times which praised the city for being 'cool, classy and supremely creative' and reflects one of the reasons Bristol appeals to students as a study location.

Academic background of 2018 recruits



Taught Year

The first year of our programme combines taught material (mandatory units and an extensive choice of optional units), group and individual problem-based projects, and enterprise/innovation skills training as a foundation for PhD research in subsequent years.

The flexiblity of our programme enables students joining from varying academic backgrounds or who have been working in industry to enhance their knowledge.

Group project

The unit introduces training in collaborative working, an essential skill for engineers who will work in teams and need to understand other disciplines and vocabularies, and also other cultures. This year's project was a feasibility study of using astronomical pulsars to provide a back-up to clock distribution by GPS, which has a number of vulnerabilities. The basic technique is known to be feasible but the project focused on the requirements for a reasonably compact and low cost radio telescope with sufficient performance to track and "decode" a number of stronger pulsars; and the necessary signal processing.

The team investigated a number of approaches and showed that with current low-cost SDR hardware, when combined with open-source signal processing software, a reasonably economical solution capable of mounting for example on a data centre roof, would be possible. The results were presented at a Cambridge Wireless event. The project was guided by Professors Kevin Morris and John Haine (visiting).

Enterprise

To ensure students have an appreciation of how research can be applied in the commercial world, all our students participate in a bespoke unit on Enterprise. This unit is unique to the CDT in Communications with case studies from the communications sector being used to illustrate concepts. This year the activities included studying business modelling, the analysis of business plans and finance, and seminars from speakers working in the communications industry. The students' assessment required them to form small teams to create business plans that they pitched to a panel of industry experts and entrepreneurs.

Individual project

During the summer students undertook an individual research project that produced the in-depth literature review for their PhD studies, giving them a 'head start' on their research. A number of the projects are co-funded by our industrial sponsors who also provide mentors and access to their facilities.

Research & Training

It has been a busy year for the Communications PhD students who have produced significant research developments, presented at numerous conferences around the world and developed both their technical & broader skills through training workshops.

Jenny Chakravarty was one of the finalists in the Bristol final of the Three Minute Thesis competition where she had to deliver a spoken presentation on her research topic 'Security over the air for 5G and beyond' with just one slide and in no more than 180 seconds. The annual competition provides postgraduates with the opportunity to practise communicating their research to a public audience.

Pawel Kowalski has been on a secondment as a Research Fellow at NATO STO Centre for Marine Research and Experimentation in La Spezia, Italy, where he was a member of the maritime surveillance working group. This enabled him to incorporate research undertaken as part of his PhD in a more realistic user case whilst simultaneously doing research on different aspects of information fusion to contribute to his PhD.

Douglas Harewood-Gill was a member of the runner-up team (tourism) at the 1st 5GCity Hackathon in Bristol, designed to encourage the participants to learn about 5G and develop proto-type applications using part of the Bristol based 5G infrastructure. The event attracted participants from the UK, Latvia, Russia, China & India with different academic backgrounds including electrical and electronic engineering, geology, linguistics and computing.

As part of the EU H2020 Multidrone project, CDT student Stephen Boyle, with Dr Aaron Zhang and Professor David Bull, has helped to create an advanced simulation tool for drone cinematography. Following extensive discussions with drone cinematography experts we concluded that the creation of simulations based on actual shooting environments would be useful for shot selection, flight planning, training and rehearsal for (multiple) drone operation. Such a tool would enhance productivity, improve safety, increase responsiveness and ultimately improve the quality of viewer experience. Forward planning of drone flights would ensure safety margins to buildings, crowds and other features. Camera shots could also be designed to provide suitable coverage of any landmarks which need to appear in-shot. Rehearsals could take account

of the dynamics of the event, allowing exploration of multiple scenarios.

Postgraduates have participated in various tehnical skills training courses such as the ‘Modern digital RF transceivers using high-speed ADCs and DACs’ course organised by Rohde & Schwartz. They have also attended European Summer Schools such as the Machine Learning Summer School (Moscow), the ESoA/COST-IRACON Joint Training School on ‘Mobile radio propagation for 5G and beyond’ and the Deep Learning Summer School (Warsaw).

In September CW (Cambridge Wireless) held a well-received joint Radio Technology and Academic Industry SIG event ‘Radio Technology for 5G - making it work’ which involved a number of CDT Communications postgraduates, alumni and staff.

The Centre was also delighted to host a variety of visitng speakers from academic and industry who have shared their expert knowledge.

Dave McEwan presented his research at the RISC-V meet-up in Bristol, attended by many prominent engineers and computer scientists in the region and hosted by his sponsor UltraSoC. He also presented at the RISC-V EMEA Workshop in Zurich and assisted with demonstrations.

David Reyes’ COST IRACON technical paper on ‘Novel over-the-air test method for 5G mmWave devices with beam forming capabilities’ was featured in the COST IRACON November newsletter.

Abia Amin presented her research on ‘Statistical security in the Internet of Things’ at the BSides Bristol infosec event attended by Cyber Security professionals.

Postgraduate students established the ‘Maths of Communications’ reading group to enable interested students from both Communications and Mathematics to meet to discuss current research, gain insight into other areas of communications and mathematics, and to talk about their own research.

Several of our alumni have had significant research recognised. Dr Ioannis Mavromatis’ research paper on driverless cars has won the Popularity Award at the 2018 IEEE Vehicular Networking Conference (VNC) in Taipei. Dr Michael Collett’s research on optically tunable microwave antennas for 5G applications has been published in IEEE Transactions on Antennas and Propagation. The research could dramatically improve the performance of future communication and radar systems that without this technology may not be able to implement certain types of 5G systems.

Dr Leo Laughlin gave a presentation to the guests at the EPSRC Pioneers competition where he discussed the benefits of winning the competition in 2015.

Winners of TechWorks 2018 Award

A collaboration with one of our sponsors has been awarded one of the highest accolades in the UK deep tech industry, for a new wireless technology that will transform 4G and 5G global roaming capabilities.

The collaboration between u-blox, Communications academics and a CDT alumni who is now a post-doc researcher, came first in the Research Collaboration category at the TechWorks Awards 2018, which celebrated the year's key electronics innovations, people and companies from across the UK and Ireland. The Bristol and u-blox collaboration, which began in 2012, won for its R&D project on Reconfigurable Wireless Transceivers for Global Connectivity.

Mark Beach, Professor of Radio Systems Engineering at the University of Bristol and Manager of the Centre, said: "This has been a truly unique collaboration and most rewarding to see it yield such a high calibre outcome. We will continue to develop this exciting technology with our partners."

By bringing together u-blox's commercial know-how and experience in wireless product design, and Bristol's expertise in waveform cancellation, the team have developed a novel, tuneable, radio architecture for mobile devices. The design facilitates global roaming on 4G and 5G, provides seamless spectrum access across diverse and fragmented frequency ranges, and is the first standards compliant and commercially viable circuit of its type.

Jim Connelly, Director, u-blox Cork, said: "We are thrilled to have won this award and it is a remarkable achievement given the strength of the competition in this category. This has proven to be a very successful collaboration with the University of Bristol and will continue to be so."

The team have jointly addressed this global challenge through collaborative R&D since 2012. PhD sponsorship and mentoring of Leo Laughlin, under the supervision of Professors Mark Beach and Kevin Morris, and industrial mentoring by John Haine, Kalim Khan and Micí McCullagh, has culminated with a highly novel Frequency Agile Frequency Division Duplexer solution. In addition to the 9 conference and 7 journal publications, including a recent paper in the prestigious IEEE Transactions on Microwave Theory and Techniques, a standards compliant laboratory prototype has been designed, built and tested through this collaborative venture.

Leo Laughlin added "We are absolutely delighted that our hard work on this project has been recognised with this award. The success of this project was only possible through the close working relationship of this academic/industrial team, which has allowed us to develop and apply novel radio technologies to target a highly specific commercial need."

2019 International Conference on Embedded Wireless Systems and Networks (EWSN) Dependability Competition Winner

Michael Baddeley won 2nd place in the 2019 International Conference on Embedded Wireless Systems and Networks (EWSN) Dependability Competition held in Beijing as part of a team from Toshiba's Bristol Research & Innovation Laboratory (BRIL), who sponsor his PhD.

The EWSN competition, held between 25-27th February 2019, is a highly selective single-track international conference focusing on the latest research results on embedded systems and wireless networking.

This highly competitive event benchmarks low-power wireless Internet of Things (IoT) solutions on a 50 node testbed, pitting the teams against various interference levels and evaluating them on reliability, latency, and energy.

Competing against 11 other groups from academia and industry, the team were runners-up in both the data collection (monitoring) and data dissemination (actuation) categories. The entry, based on Michael's PhD research into Software Defined Networking (SDN) in IoT, demonstrates how Concurrent Transmissions (CT) and Synchronous Flooding (SF) techniques can be used to provide a configurable and programmable control plane for low-power wireless networks.

On winning the award, Michael commented: "This accolade recognises that SDN can be part of sensor networks, and low-power wireless IoT".

Public Lecture

Fake news to fake data:
manipulation of the futre Internet

Professor David Rogers (Founder & CEO, Copper House)

Thursday 27 September 2018

In September 2018, Professor David Rogers MBE delivered our annual CDT lecture on the topic 'Fake news to fake data: the manipulation of the future Internet' to a large public audience. He discussed our future trust in the Internet of Things, connected economies and how to help prevent artificial intelligence systems from easily being gamed by adversaries.

Professor Rogers is a mobile phone and IoT security expert who runs Copper Horse Solutions Ltd, a software and security company based in Windsor, UK. He chairs the Device Security Group at the GSM Association and sits on the Executive Board of the Internet of Things Security Foundation. He is a Visiting Professor in Cyber Security and Digital Forensics at York St John University and teaches Mobile Systems Security at the University of Oxford. He has worked in the mobile industry for 20 years in security and engineering roles. Prior to this he worked in the semiconductor industry.

Postgraduate Research Conference

The 2018 Annual Student Research Conference for postgraduates, academic and industrialists was held on the 26th September.

Postgraduates presented their research on a range of topics that included ‘Heterogeneous information fusion’, ‘Propagation models for massive MIMO’, ‘Multi-drone cinematography’ and ‘Analysing interface bonding in 5G WLANs’.

The conference gave attendees the opportunity to discuss the latest developments in communications.

Mark Graham and Michael Wilsher, two of our current postgraduate students, gave a presentation on how the Centre had provided them with the opportunity to apply their undergraduate degrees in mathematics to real-world research challenges in engineering.

The Centre welcomed Andy Lunness as our guest speaker, who gave a keynote address on activities and innovations in his company Blu Wireless.

Bristol's Enterprise Campus

The University of Bristol is investing over £300m in a new Enterprise Campus at Temple Quarter – next to Temple Meads Station in Bristol. This is due to open in 2022 and offers an opportunity to reimagine the future as one of the world's great civic universities. It will not only provide economic growth and job creation for the region, but will also allow us to develop a new relationship with the city, new educational and research opportunities, and secure the University's future for generations to come.

Located in the heart of the city in one of Europe's biggest regeneration programmes, the campus will help transform a neglected area into a vibrant new quarter of the city.

Innovation will be at the heart of our new campus, much of which will be closely aligned to our CDT activities. New technologies, discoveries and societal change need new methods of innovation and collaboration. We are working with business and community partners to help solve the pressing global challenges of society and contribute to the four grand challenges in the government's industrial strategy: artificial intelligence and big data; clean growth; the future of mobility; meeting the needs of an ageing society. From driverless cars and highly secure systems, to future internet, 5G and beyond, creative technologies, quantum engineering and AI, we will tackle the challenges of tomorrow in an interdisciplinary and flexible environment, bringing together both academia and industry. Businesses will be co-located with us on the campus. They will partner with us on cutting-edge research projects and have access to expertise, learning, facilities, equipment and talent. Our students will take on real-world challenges connecting with businesses and enterprises and working across disciplines. Work on the campus will benefit Bristol and will be shared with cities around the world.

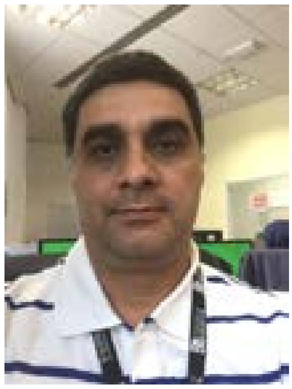
Our academics, researchers and students will mingle with SMEs, start-ups and multinational corporations in a purpose-built creative hub centred on innovation and collaboration.

Independent, inventive and enterprising, the city and university together offer the combination of skills and attributes that make Bristol a vital centre for transformative innovation.

PhD Projects commenced 2018

Khalid Al Mallak

Millimetre wave vehicular channel characterisation, modelling and performance optimisation for 5G communications



Millimetre wave communications is currently an area of intense research. It will revolutionaise the capabilities of 5G cellular communications. In particular, the communications between vehicles and vehicular infrastructure requires extremely high data rates and very low latency. Therefore, to consider a realistic performance assessment of a vehicular channel, it is necessary to develop propagation channel models at millimetre waves that reflect the true behaviour of the radio channel. This needs to consider the deployment of realistic antenna arrangements. To address this problem, this research utilises the millimetre wave channel sounder system at the University of Bristol and over-the-air measurement capability at NPL. These together are able to characterise and construct propagation vehicular channel models for millimetre wave communications as well as optimising performance.

Abia Amin

Statistical security in the Internet of Things

Cyber-security is a major challenge within the Internet of Things (IoT) as recent research found 250 vulnerabilities in the most popular ten IoT devices. This project focuses on statistical approaches to detect anomalies in IoT networks. Using anomaly detection for IoT security application is challenging especially in high-density IoT devices scenarios. The probability distributions of normal and anomalous behaviour are unknown and also the problem is inherently high-dimensional as we are interested in high-density IoT scenarios. The goal of this project is to develop a decentralized and real-time anomaly detection algorithm that can achieve a pre-defined performance limits such as the delay between the detection time and the actual attack time and also the false positive alarm rate of the algorithm.

Henry Bromell

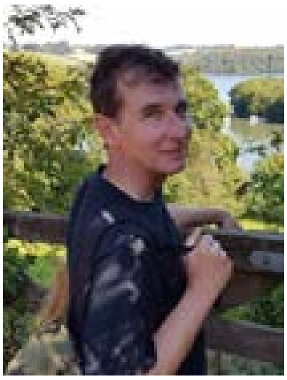
Exploring CSI over time in massive MIMO for 5GNR and beyond

Massive MIMO makes use of channel reciprocity and downlink precoding to achieve enormous advances in spectral efficiency over earlier radio access networks, but is limited in how far it can scale by pilot contamination, computational complexity, and mobility performance. Currently CSI information is typically used only for channel estimation in a single slot, which allows downlink precoding to occur within the coherence time of the channel, after which it is discarded.

This project aims to investigate whether artificial intelligence techniques such as machine learning can be used to identify and extract longer term patterns from CSI to improve massive MIMO performance. This is likely to include work in areas such as pre/decoding performance, enhancing resistance to malicious pilot contamination, improving mobility performance and investigating cell free technologies for beyond 5G. Access to Bristol’s Masive MIMO testbed should enable work to be performed on real world datasets gathered in fully known environments.

Roger Green

Load pull correction for large antenna arrays



Antenna arrays for Massive MIMO and for beam steering require sub wavelength distances between elements. This causes a phenomenon known as load pull due to the mutual coupling between elements in the array. The power amplifiers driving the array would be subjected to a load mismatch which will cause them to operate less efficiently and will ultimately adversely affect the directionality and data throughput of the system.

This project addresses the load pull problem using modelling techniques to predict the effect in a varying number of configurations. Compensation techniques incorporated into digital predistortion will be explored as well as analogue solutions. As the behaviour is non linear, a deterministic approach may not yield a suitable outcome therefore other methods such as machine learning will be investigated.

Peter James

Cheap & clever phased arrays

Phased arrays are becoming increasingly critical across a wide variety of applications ranging from 5G to satellite communications. The prospect of physically very small antennas at millimetre wave frequencies would make implementing electronically large antenna arrays at the terminal a possibility. However, these are accompanied by other challenges that would need to be tackled by intelligent phased array architectures such as the trade-offs of antenna array gain versus size, weight, power and cost. On the other hand, low elevation angle performance would be very critical for satellite phased array terminals especially on moving platforms.

This research addresses issues such as interference mitigation, efficient power usage and low elevation angle performance, explores different beamforming techniques and will develop prototypes of proposed array architectures.

Sanat Nagaraju

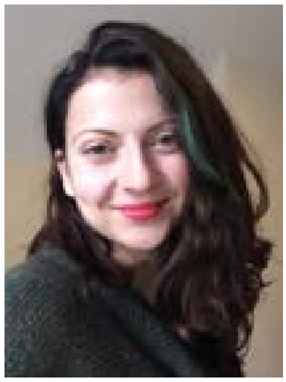
An assessment of L-systems for media coding & decoding

Modern image & video encoding, and decoding systems employ pixel-based coding without much consideration of the image scene composition. Existing encoding standards typically use a transformation engine (e.g. DCT), quantisation of the residual blocks followed by entropy coding which provides a desired compression ratio for transmission over a bandwidth limited channel. The pixel-based coding is applied to the entire blocks & frames and only limited content composition of the image is exploited for compression.

This project explores alternative methods of encoding based on the composition of image to further improve the amount of compression achieved. The exploration considers variations between the repetitive and scalable patterns available in most images and exploits the statistical redundancy available in the composition of images. The technique using Lindenmayer Systems is currently well suited for rendering scenes in computer graphics & animations, and this project is exploring the use of this technique for image coding.

Chrys Paschou

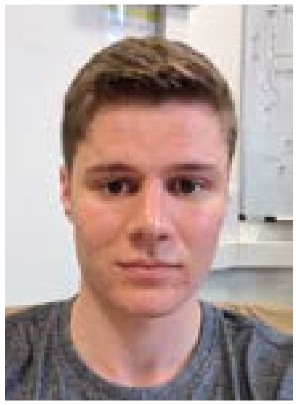
Physical layer security and friendly jamming



This project aims to provide confidentiality in wireless communications in the presence of a multiple-antenna eavesdropper whose channel state information is unknown at the transmitter. Conventional physical layer security uses beamforming and Artificial Noise (AN) in order to increase the secrecy gap, i.e., the difference in the quality of the legitimate channel and the eavesdropper's channel. Most AN schemes found in the literature assume Gaussian input signalling and they are not effective for practical transmission schemes. An alternative way to degrade the eavesdropper's channel is proposed. It is based on distributed transmit-beamforming and makes no assumption on the transmission scheme used. Decoding at the receiver only requires XORing and can be performed by any device such as a light-wear sensor.

Jonathan Thomas

Reinforcement learning for network management applications



Mobile communications networks are becoming increasingly heterogenous in terms of both the physical networks and the services which they aim to provide. The additional complexity this introduces is likely to result in the near-optimal management of these systems being an unsurmountable task for current solutions. Currently this is mostly performed by human operators, but their capacity is unlikely to be able to efficiently scale or provide the agility necessary for future networks, as such autonomous solutions are inherently attractive. A potential solution is Reinforcement Learning (RL) which provides methods for learning a behavioral policy through direct interaction with a selected system. RL has seen significant success in a range of domains but still suffers from low sample efficiencies and reliability related problems. As such, this work aims to mitigate some of these problems and provide RL based solutions which can quickly and reliably solve problems within communications.

Robert Zakrzewski

Detection of unusual behaviour and actions in communication systems

Proliferation of malicious users and devices in the global network makes an automated, explainable and robust protection the paramount requirement. Methods for anomaly detection using artificial intelligence with multi-modal information processing, and the techniques for threat localization can be used to enable automated and robust countermeasures. Effectiveness of detection process is enhanced by distribution of agents and fusion of complementary information to support incident classification tasks. The distribution implies collaborative nature of the system and heterogeneity of the environment. Methods and algorithms enabling knowledge acquisition, micro-operations, co-learning and knowledge transfer are the building blocks for the integration of the global system with various classes of systems including constrained devices. Last but not least, models need validation which brings the key challenge with datasets accuracy and multi-modal information handling.

Graduates

Congratulations to our postgraduates who have graduated in the last twelve months and who are now working in industry or academia around the world.

James Birchall .... *'UE uplink power distribution for M2M over LTE'*

Wael Boukley Hasan .... *'On evaluating the practicality of using massive MIMO in real-world scenarios and identifying solutions to operational deployments'*

Paolo Enrico de Falco ...... *'Load modulation of harmonically tuned RF power amplifiers'*

Joe Hollinghurst .... *'Enabling software defined networking in high criticality networks'*

Ioannis Mavromatis .... *'5G communication framework for smarter autonomous vehicles'*

Alex Tibbs .... *'Bio-inspired imaging polarimetry'*

The Team

Professor David Bull

Director

Professor Mark Beach

Centre Manager &
Year 1 Tutor

Dr Simon Armour

Admissions Tutor, Taught
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Professor Kevin Morris

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