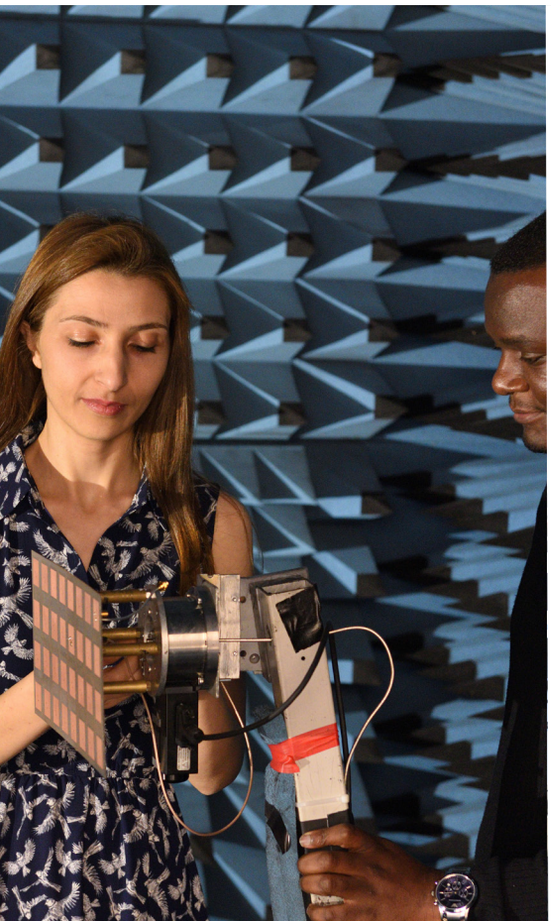
University of BRISTOL

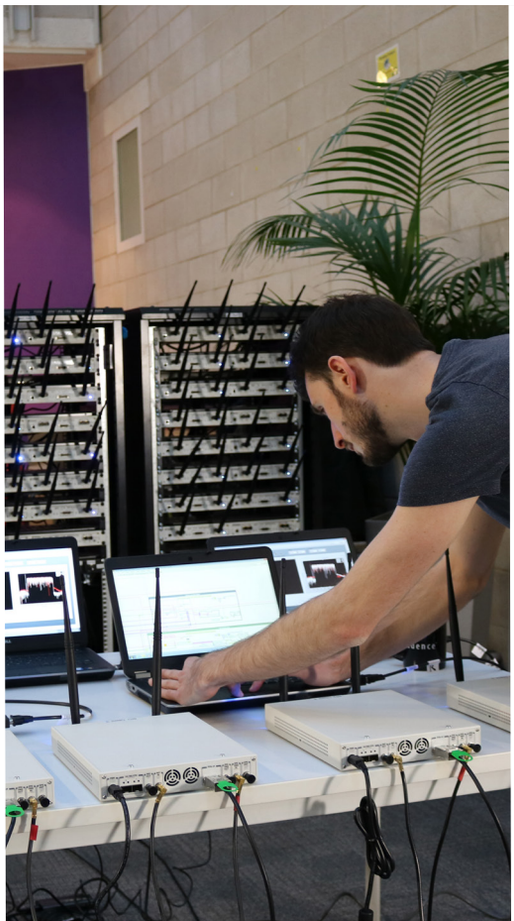
EPSRC
Engineering and Physical Sciences Research Council

EPSRC Centre for Doctoral Training in Communications

Annual Report

2015 - 2016





Foreword

It is with great pleasure that we bring you the latest Annual Report from the EPSRC Centre for Doctoral Training in Communications.

Since the launch in 2011, our CDT has recruited five intakes, with a total of 48 students now studying in the Centre. The first cohort are now close to, or have completed their PhDs, having made significant contributions worthy of publication in leading journals, key international conferences and public demonstrations of their research. Several researchers have filed patents and also received external prizes in recognition of their research. Some students have enjoyed their PhD studies in Bristol so much that they have elected to stay, and have been successful in obtaing postdoctoral research posts.

At the other end of the spectrum, the fifth cohort are concentrating on pursuing the first year taught units before commencing their research projects.

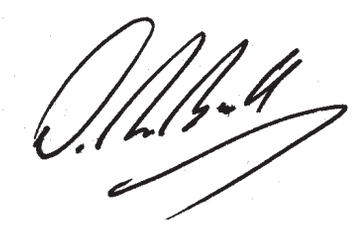
We are now recruiting the sixth cohort of students who will be the first group under the new CDT grant. By the end of this grant, the Centre will have recruited, trained and developed the skills of over 80 future leaders in the Communications sector.

In 2015, we were delighted that Dr Paul Martin (Chief Technology Officer, Plextek Consulting), was the guest speaker for our Annual Public Lecture, where he spoke to a large audience on the subject of 'The Benefits and Challenges of Connected and Autonomous Vehicles'. A very successful Annual Student Research Conference was also held at M Shed in Bristol on the following day.

Notable achievements during the last 12 months have included researchers from the Centre in collaboration with the University of Lund and National Instruments, establishing the world record for 5G wireless spectrum efficiency, Leo Laughlin winning the EPSRC Technology Everywhere category in the EPSRC UK ICT Pioneers competition 2015 and a team of students winning the Efficiency Power Amplifier Student Design Competition at the prestigious International Microwave Symposium (IMS) 2016. Professor Joe McGeehan, Chair of the CDT, was awarded a Special Ambassador award at the Edge Awards for his long-standing contribution to the technology sector in the region.

We are grateful for the ongoing support from EPSRC and our industrial partners. Their engagement provides relevant and challenging research projects and also provides complementary skills training and new equipment facilities.

I hope this report will give you an insight into the personalities and the activities associated with our Centre over the past year. Please enjoy reading it and do not hesitate to get in touch if you would like to



Professor David Bull
Director, EPSRC Centre for Doctoral Training in Communications

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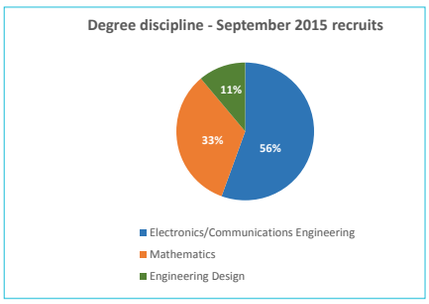
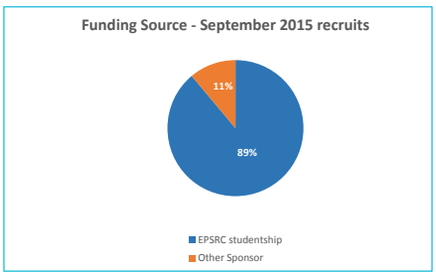
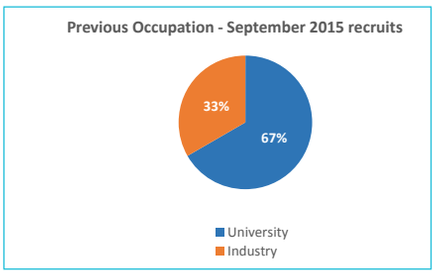
Recruitment

Nine enthusiastic new students, with degrees in electronic engineering or mathematics, joined the Centre on the 21st September to commence their postgraduate research careers. Some students also have relevant industrial experience.



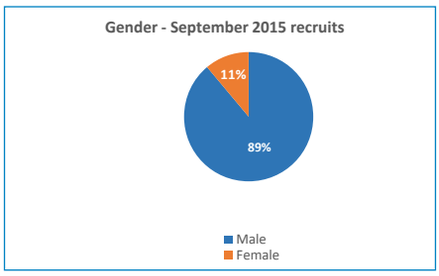
Most students are being funded by EPSRC together with additional funding from industry. The additional funding support from industry enables us to recruit the very highest calibre students by offering enhanced stipends and opportunities. One student is been funded through a scholarship from his home country. Students are also attracted to the CDT in Communications by the many opportunites to work with industry and secondments with companies in the UK and overseas.





As in previous years, a number of our new recruits are returning to education after working industry as they wish to further develop their skills to enhance their career options.

On graduating the students will be highly employable in both industry and academia.

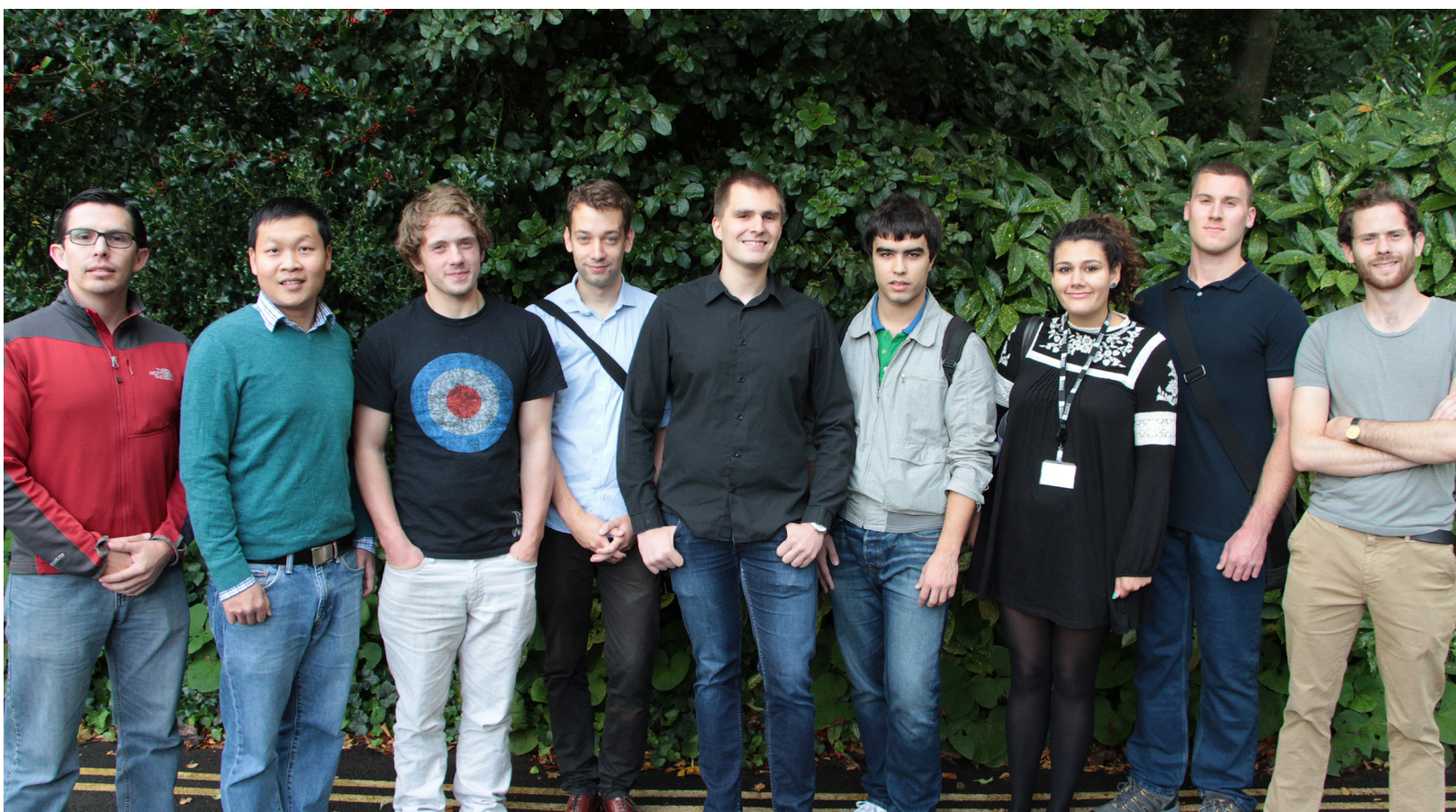


The students who began the programme in September 2015 are the last group to be recruited under the original grant. A further three cohorts, totalling 30 students will be recruited for entry in 2016, 2017 and 2018 under the new grant.

"The CDT has offered me a great opportunity to expand my knowledge in mobile communications in both academic and industry sectors."

Wael Boukley Hasan
Student

2015 Recruits



Taught Phase

"The opportunity to first develop a deeper and broader understanding of the field enabled me to make the best decision about which area to focus on in my PhD, and gave me a strong foundation on which to build a career in communications."

Stavros Typos
Student

The first year of the programme has been designed to provide students with a broad range of fundamental background knowledge to develop their core skills in mathematics and comunications engineering. Students were required to take compulsory units but were also able to pursue their interests in particular topics through the selection of optional units. Comments on the unit choice options from the previous cohort were taken into account when deciding which units the cohort would be able to select from this year.

From next academic year (2016-2017), students will be divided into 3 streams relating to previous subject knowledge and their unit selection will reflect areas of prior expertise (electronics, maths or related discipline eg. physics or computer science).

In addition, students will continue to be required to study Enterprise & Innovation, participate in a Group Project and undertake an Individual Research Project.

Enterprise

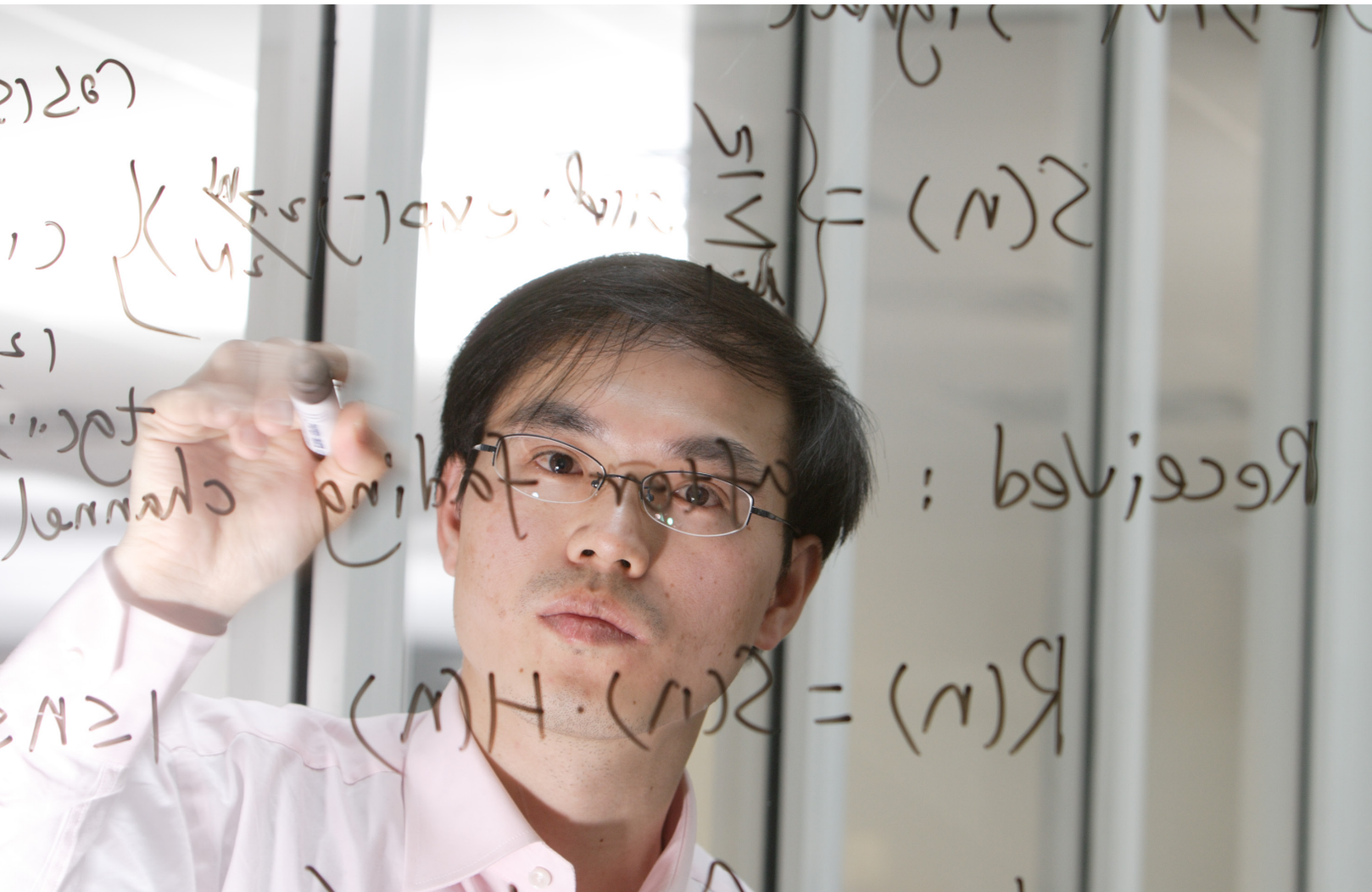
All students participated in Enterprise training via a bespke course led by the University's Entrepreneur in Residence. The course also included contributions from senior experts in management and innovation working in the communications industry. Students were assessed by the submission of an analytical report on a business case and a presentation on why they would or would not invest in the company.

Group Project

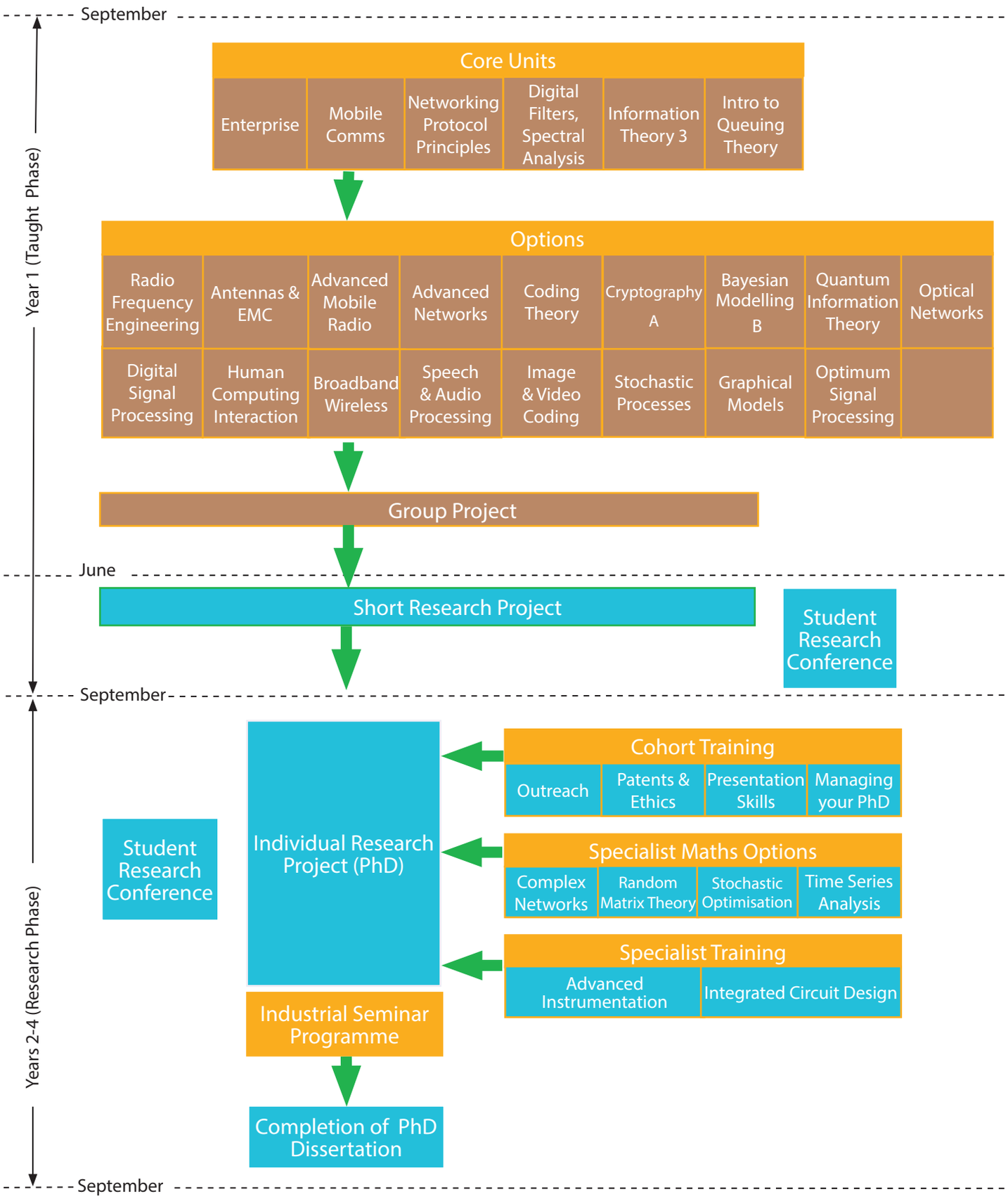
Students were divided into two teams for the Group Project, which was supported by Ofcom. The project required them to undertake research on WiFi.

Individual Research Project

Students completed an assessed short Individual Research Project during the summer, which provided the literature review for their PhD studies. In most cases the projects were proposed by industrial sponsors with students having a mentor from the sponsoring company.



Programme Specification 2015-2016



Skills Training

Throughout their four years of study, students are encouraged to create Personal Development Plans and to participate in training organised by providers across the University, the CDT in Communications and via industrial supporters. Students in the taught year receive intensive training on enterprise and innovation skills.

Some examples of skills development opportunities taken by students are below.

Students in their first year of research established a 'Present a Paper' club where members give short presentation to colleagues on a paper they have read and take Q&As to develop their skills for conferences.

Paul Harris is working on the massive MIMO testbed through the Bristol is Open project; the first of its kind in the world, and the only massive MIMO testbed in the UK. To assist with the research training, during the summer Paul spent two months on secondment with National Instruments (NI) at their headquarters in Austin, Texas where he familiarised himself with and extended the development of the underlying software architecture. He also helped to develop a prototype system for future 5G communications. A working subset of the technology was presented at NI's largest annual conference, attended by thousands of engineering professionals, and demonstrated simultaneous high-definition video streaming from two mobile phones using half the resource typically required in the 4G systems used today.

In January students participated in specialist training provided by National Instruments on the new NI LabVIEW Communications System Design Suite. The workshops were held at Lund University in Sweden and also attended by researchers from other European Universities including Leuven, Aalborg and Lund as well as National Instruments employees from around the globe.

James Birchall, in his first research year, attended the 'Waveforms and Network Architectures for the IoT in 5G' Summer school at Euracon in France and undertook training in 'PCB Design for RF and High Speed Digital Applications' at the Technology Academy in Fleet.

Students attended a bespoke technical training day in Bristol on Anite's equipment for 5G Channel Modelling. Delegates from Sheffield University and Industry also participated.

Students took the opportunity to develop key skills for their future careers by attending training sessions on 'Completing your PhD', and 'Introduction to Research Grant Applications'.

Jenny Chakravarty attended the '7th Women's Engineering Society (WES)' conference 2015 at Aston University where delegates shared their passion for engineering and technology, and discussed career opportunities.

George Margelis participated in the 'Intensive Programme on Information & Communication Security' and eCrypt.net's 'School on Design for a Secure IoT'.

Paul Worgan organised a workshop at the Pervasive Media studio in Bristol for those interested in engaging in an open discussion around technology being developed that allows users to quickly share power between mobile devices, using inductive power transfer and the design and social implications, assisted by mock-ups and practical explorations.

Research Highlights

Students have worked closely with their academic and industrial sponsors on their research; with some spending time on secondments or participating in company activities. Examples include, James Birchall presenting work to his sponsors, u-blox in Cambridge, and to their other sites around the world. Paul Harris has spent the summer in the USA with his sponsor, National Instruments. Michael Baddeley is located at his sponsors (Toshiba) several days a week.

A demonstratration of the prototype full duplex transceiver architecture developed by Leo Laughlin, in collaboration with his sponsor u-blox, was given at the IEEE Vehicular Technology Conference. The new radio transceiver design for mobile devices can tune over wide frequency ranges, and would be able to cover all frequency channels, taking smartphone technology closer to global roaming on 4G. A paper on the work was published in IEEE Transactions on Circuits and Systems.

Papers have been published in a number of key journals and at international conferences on wide range of communications topics. Some examples are detailed below.

G Margelis has been investigating emerging protocols that will connect the Internet of Things and bring into fruition the concept of Smart Cities. His work has focussed on the security properties and the performance of Sigfox's and Ingenu's networks. The results of this work were presented at the World Forum of the Internet of Things in Milan, Italy.

Alex Tibbs attended the Biouas Bio-inspired Systems and Technologies State of the Art Review, to gain new insights into the current state of bio-inspired sensing.

A cross research theme paper authored by CDT students, was presented by Paul Worgan at the 2015 IEEE 2nd World Forum on Internet of Things in Milan, Italy.

In February, Brett Hosking attended the SPIE conference on Electronic Imaging and presented his work on a novel method of increasing the quality of video at very low bitrates.

Themis Omirou participated in the ICT (Innovate Connect Transform) Exhibition in Lisbon, Portugal where the Acoustic Levitation project was exhibited. The project was listed as one of the top 10 must-see projects. out of 150 projects at the exhibition.

In April 2016, *The Economist* featured the PowerShake project being developed by Paul Worgan and colleagues in the Bristol Interaction Group (BIG). The project is investigating power as a shareable commodity between mobile (and wearable) devices to enable users to control the balance of power levels in their own devices (intra-personal transactions) and to trade power with others (inter-personal transactions) according to their ongoing usage requirements; supports ongoing/ continuous tasks (transferring at ~3.1W); fits in a small form factor; and is compliant with electromagnetic safety guidelines charging efficiency while providing charging efficiency similar to commercial inductive power transfer standards (48.2% PowerShake vs. 51.2% in Qi).

In March 2015, CDT students showcased their work on 5G communications at an Ofcom event attended by industry, academia and policy makers.

In May, a team of students - Paolo de Falco, James Birchall and Laurence Smith - won the prestigious High Efficiency Power Amplifier Student Design Competition at the International Microwave Symposium (IMS) 2016. They were required to design a power amplifier that had to comply with minimum specifications in terms of gain and output power levels.

Also in May, research undertaken by students in the CDT, engineers from the universities of Bristol and Lund, working alongside National Instruments (NI), set a new world record in 5G wireless spectrum efficiency where it was demonstrated how a massive antenna system can offer a 22-fold increase in spectrum efficiency compared with current 4G cellular technology.

In November, the first of our students from the initial cohort passed their viva and was awarded their PhD in February 2016. A number of other students graduated in August.

"The 5G wireless spectrum efficiency demonstration was made possible by the cohort training offered within our Centre. The CDT in Communications gives Bristol a unique edge to conduct activities at scale."

Professor Mark Beach
Centre Manager

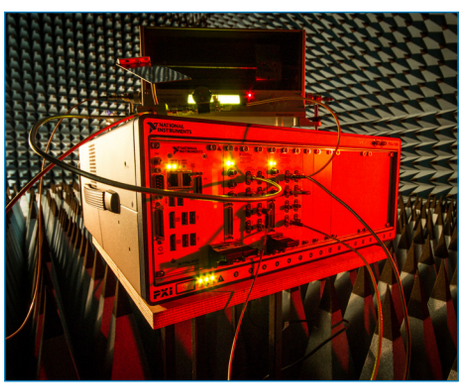
EPSRC ICT Pioneers Award

"We are justifiably proud of Leo and this award exemplifies both his technical contributions to the field of full duplex wireless and skills of conveying his research to a non-specialist audience. Equipping our students with such skills is at the heart of our training at Bristol."

Professor Mark Beach,
Centre Manager

Leo Laughlin, a student in the first cohort of students recruited to the Centre when it was established in 2011, has been named as one of the winners of a prestigious national competition for his work on a new technology that could fundamentally change future wireless communications.

Leo won the Technology Everywhere category in the UK ICT Pioneers competition 2015 which recognises researchers who are pioneers in Information and Communication Technology (ICT).



The UK ICT Pioneers scheme is a unique partnership between the Engineering and Physical Sciences Research Council (EPSRC) and key stakeholders that aims to recognise the most exceptional UK PhD students in ICT-related topics who are able to communicate and demonstrate the excellence and exploitation potential of their research.

Leo's work on bi-directional radio communications could result in a change to the way we design wireless devices and has the potential to increase data rates and network capacity, reduce power consumption, create cheaper mobile devices and enable global roaming.

Working in collaboration with his supervisors, Professor Mark Beach and Dr Kevin Morris and industrial mentor Professor John Haine at u-blox, Leo has developed a novel method of minimising self-interference power in a full duplex radio system.

"I could never have achieved this without all of the support I have received from my supervisors and through the CDT. I am sure this is but one of many more successes in the CDT to come!"

Practical results demonstrated at the EPSRC ICT Pioneers final illustrated how the adaptive tuning algorithms respond when objects are placed near the antenna as well as the performance of the self-interference cancellation using novel waveform injection.

Leo Laughlin received his award from Professor Philip Nelson, Chief Executive of the EPSRC, and BBC presenter Quentin Cooper.

"It has been a pleasure to work with Leo and the Bristol CDT team on this project. We are very pleased to have had the opportunity to push this research forward and we will be continuing the association to the next phase."

Professor John Haine,
u-blox, industrial supervisor

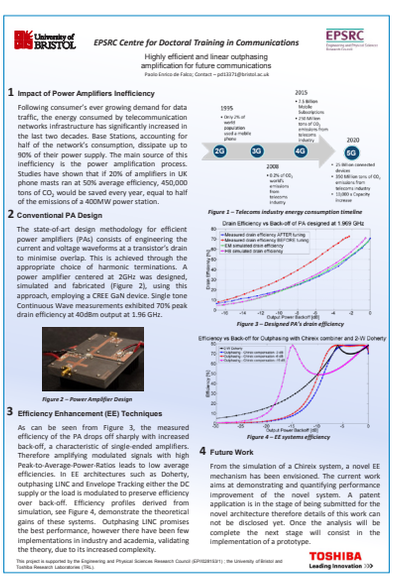
Annual Student Research Conference & Public Lecture

The 4th Annual Student Research Conference was held on the 25th September at M Shed in Bristol and attended by approximately 80 delegates (students, academics, and industry). Students not affiliated with the Centre but who had a particular interest in the research being undertaken also attended.

Research topics discussed were wide-ranging and included: 'Real-time Massive MIMO', 'Bioinspired Polarisd Light Computer Vision Systems', 'Adaptive Broadcast Techniques for Digital Terrestial Television', Flexible Duplexing for 4G Cellular Handsets' and 'Efficient Power Amplifiers for IoT Machine-to-machine Devices'.

In a change to the format used in previous years, students who had finished their first year of research gave a 5 minute 'elevator pitch' and produced a flyer on the novelty of their work. This new style of impactive presenting proved to be very popular with the audience.

Students who had just completed the first year (taught) of the programme presented posters on their initial background research and were subject to intense questioning from delegates. Final year students gave detailed presentations on their research and third year students presented a poster. There were also plenty of opportunities for informal discussions between students, academics and industry throughout the event.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Highly efficient and linear outphasing amplification for future communications

Paolo Enrico de Falco; Contact – pd13171@bristol.ac.uk

1 Impact of Power Amplifiers Inefficiency

Following consumer's ever growing demand for data traffic, the energy consumed by telecommunication networks infrastructure has significantly increased in the last two decades. Base Stations, accounting for half of the network's consumption, dissipate up to 90% of their power supply. The main source of this inefficiency is the power amplification process. Studies have shown that if 20% of amplifiers in UK phone masts ran at 50% average efficiency, 450,000 tons of CO_2 would be saved every year, equal to half of the emissions of a 400MW power station.

1995
• Only 2% of world population owned phone
• Mobile phone

2015
• 7.5 Billion mobile subscriptions
• 250 Million tons of CO_2 emissions from telecoms industry

2020
• 25 Billion connected devices
• 850 Million tons of CO_2 emissions from telecoms industry
• 10,000 x Capacity increase

2G 3G 4G 5G

2008
• 0.2% of CO_2 world's emissions from telecoms industry

Figure 1 – Telecoms industry energy consumption timeline

2 Conventional PA Design

The state-of-art design methodology for efficient power amplifiers (PAs) consists of engineering the current and voltage waveforms at a transistor's drain to minimise overlap. This is achieved through the appropriate choice of harmonic terminations. A power amplifier centered at 2GHz was designed, simulated and fabricated (Figure 2), using this approach, employing a CREE GaN device. Single tone Continuous Wave measurements exhibited 70% peak drain efficiency at 40dBm output at 1.96 GHz.

Drain Efficiency vs Back-off of PA designed at 1.969 GHz

Measured drain efficiency AFTER tuning
Measured drain efficiency BEFORE tuning
EM simulated drain efficiency
Ideal simulated drain efficiency

Drain Efficiency (%)
Output Power Backoff (dB)

Figure 3 – Designed PA's drain efficiency

Figure 2 – Power Amplifier Design

Efficiency vs Back-off for Outphasing with Chireix combiner and 2-Way Doherty

Ideal Outphasing
Outphasing - Cross-compensation 2 dB
Outphasing - Cross-compensation 1 dB
Outphasing - Cross-compensation -3 dB

Efficiency (%)
Output Power Backoff (dB)

Figure 4 – EE systems efficiency

3 Efficiency Enhancement (EE) Techniques

As can be seen from Figure 3, the measured efficiency of the PA drops off sharply with increased back-off, a characteristic of single-ended amplifiers. Therefore amplifying modulated signals with high Peak-to-Average-Power-Ratios leads to low average efficiencies. In EE architectures such as Doherty, outphasing LINC and Envelope Tracking either the DC supply or the load is modulated to preserve efficiency over back-off. Efficiency profiles derived from simulation, see Figure 4, demonstrate the theoretical gains of these systems. Outphasing LINC promises the best performance, however there have been few implementations in industry and academia, validating the theory, due to its increased complexity.

4 Future Work

From the simulation of a Chirelx system, a novel EE mechanism has been envisioned. The current work aims at demonstrating and quantifying performance improvement of the novel system. A patent application is in the stage of being submitted for the novel architecture therefore details of this work can not be disclosed yet. Once the analysis will be complete the next stage will consist in the implementation of a prototype.

The project is supported by the Engineering and Physical Sciences Research Council (EPSRC)(EP/I028153/1) | the University of Bristol and Toshiba Research Laboratories (TRL).

TOSHIBA Leading Innovation >>>

On Thursday 24th September, Dr Paul Martin of Plextek Consulting gave the Annual Public Lecture on the subject of 'The Benefits and Challenges of Connected and Autonomous Vehicles' to a large audience of students, academics, researchers, industrialists and the public.

The lecture considered the benefits and issues with the introduction of these new technologies. A number of thought-provoking challenges to engineers were presented where there is a direct link between a design and a moral dilemma.

Discussions on the implications of the autonomous vehicle technologies were continued at the reception following the lecture.

Outreach

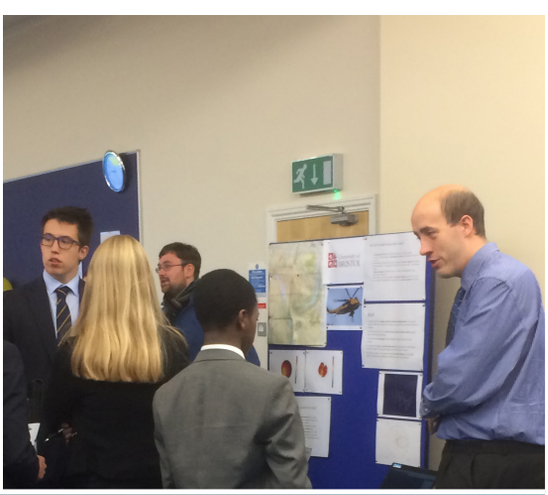
Postgraduate students devised and managed a project for Colston's School in Bristol for their Sixth Form Future Leaders Engineering Professional Project. The scheme for science had run successfully for several years with science projects from the CDT in Nanomaterials. This year the School and the CDT in Communications wished to widen the scheme to give the Sixth Formers an opportunity to undertake an engineering R & D project.

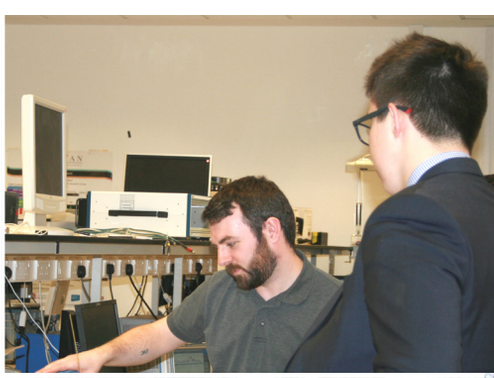
Eleven Colston students elected to participate in the project. In two teams, they were set the challenge of designing a portable antenna capable of detecting the bearing of a distress signal for mountain rescue staff to use when finding lost mountaineers. The postgraduate students provided technical guidance, workshops and seminars on basic theory and an introduction to antennas and design before the Sixth Formers began their design work using the design software 4NEC2. A visit was made to the University to test their antenna prototypes in the anechoic chamber, and after making minor alterations to the antenna they had a final technical challenge to direction find a hidden beacon under real-world conditions in a local park. They also submitted a technical report on the design.

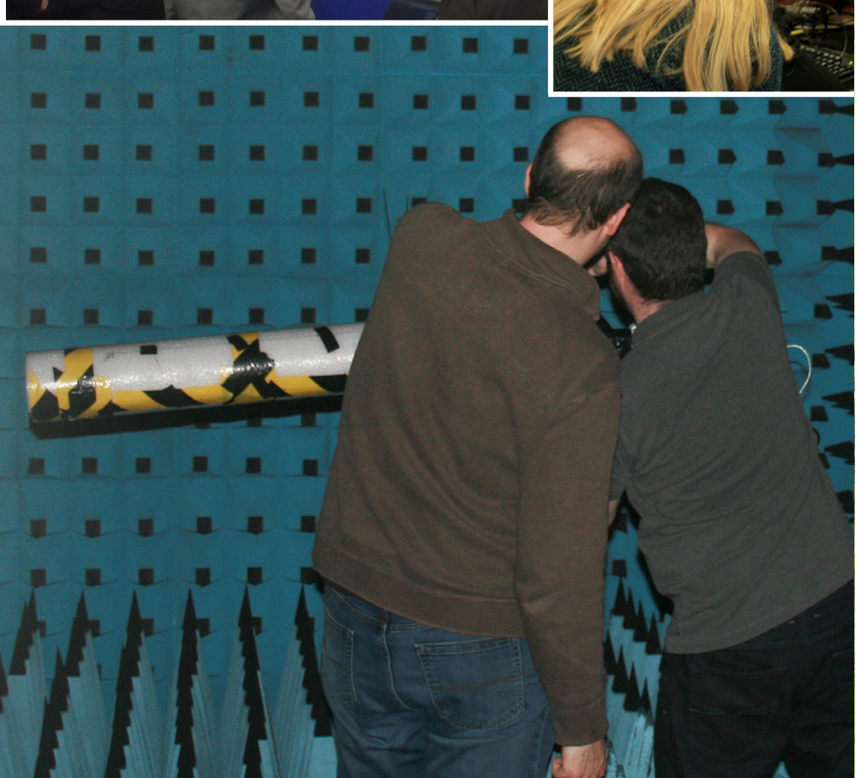
In front of an invited audience of 300 people that included members of the local press, industry and the Society of Merchant Venturers the two groups presented their experiences and results of designing, simulating, building, testing and measuring their Yagi and helical antennas. In addition to the insight gained into engineering, a range of skills including team work, project management, presenting and the self confidence gained by undertaking such a project were developed.

"The CDT provided Colston's students with an exceptional opportunity to experience the challenges of working on a demanding R & D project, and has inspired a number of our students to consider pursuing a career in engineering."

Dr Paul Hill,
Deputy Headmaster, Colston School







Student Research Projects - First Year Researchers

Student:	Michael Baddeley
Project:	Leveraging SDN to deliver Reliable, Scalable and Energy Efficient M2M Networks

The standardisation of Software Defined Networking (SDN) in recent years has allowed major businesses to overhaul their network infrastructure and deliver improved performance at reduced cost. Offering fully programmable and scalable networks, SDN enables dynamic management and reconfiguration with a global view of the network state. Along with Network Function Virtualisation (NFV), SDN has traditionally been applied to wired network infrastructure. However, rapid expansion in the number of wireless devices means they are increasingly being leveraged to solve challenges in next generation wireless networks, where Machine-to-Machine (M2M) communication will drive a large proportion of traffic growth. M2M is typically characterised by nodes in constrained and unreliable environments, with heterogeneous service requirements and bursty traffic over large wireless mesh networks. These challenges directly affect the performance, reliability, scalability and energy efficiency of M2M and IoT (Internet of Things) networks. The increased manageability granted by SDN can enable more intelligent use of resources, allowing data forwarding decisions to be taken at controller level with global network knowledge. This allows fine-grained, dynamic control over nodes, as well as providing a platform for NFV in M2M. Introducing SDN to an IoT scenario allows intelligent data aggregation in a heterogeneous network as well as interference mitigation from competing wireless technologies.

This research aims to explore the challenges inherent in M2M communication, introduce algorithms for the effective management of heterogeneous networks, and study how overcoming these issues can provide reliability, scalability and energy efficiency in IoT scenarios.

Student:	Wael Boukley Hasan
Project:	MU-MIMO Techniques for Wireless Programme-making and Mobile Delivery

Radio spectrum is now becoming a scarce and valuable resource for programme making and delivering mobile user content. The existing paradigms for exploiting the radio spectrum need to be improved and become more efficient to handle major sporting or cultural events.

Multi-user (MU)-MIMO was added to the 3GPP LTE & LTE-A standards which has significantly improved the system capacity. The success of multiple antennas per unit has encouraged the development of a novel technological shift, namely massive MIMO, which has a large number of antennas. Massive MIMO has become a strong candidate to handle the increase in the data traffic in wireless communications system. Spatial diversity in massive MIMO allows many terminals to exploit the time-frequency resources which improve the spectral efficiency.

MU-MIMO and massive MIMO offer the possibility of high data capacity to each user, with independent content, for wireless programme-making and mobile delivery.

The aim of the project is to examine the possibilities of exploiting these technologies in wireless programme-making and mobile delivery. As well as examining not just the theoretical possibilities, but also the practicalities of system channel estimation and data distribution and co-ordination in realistic environments. Different approaches will be investigated and tested (e.g. Channel pre-inversion techniques, interference alignment, Blind IA) to identify which is most suitable for different scenarios.

Student: Henry Brice
Project: Massive MIMO Propagation Models

The demand for capacity within existing mobile networks continues to increase as more subscribers and more devices join the networks and as data-rich applications become more popular. The new 5G telecommunications standards aim to respond to such demand. A promising approach to increasing capacity and reliability within the context of 5G is Massive Multiple-Input Multiple-Output (MIMO) where many transmit antennas are used relative to the number of users. The deployment of Massive MIMO systems requires the development of propagation models, which is the focus of this project, in order to simulate accurately the particular channel characteristics within different environments so that the design of the networks can be optimised in terms of reliability and efficiency.

This project approaches the particular challenges of Massive MIMO propagation models through the use of simulation and statistical techniques and through the analysis of data obtained from world-leading facilities at the University that include the ray-tracing system which enables the creation of models of multi-path propagation within urban environments such as Bristol and which can be enhanced through the inclusion of antenna parameters. The project also uses the Massive MIMO testbed 28 element test-bed made available through the Bristol is Open experimental facility and which is currently the only one in existence in the UK.

Student: Benny Chitambira
Project: Massive MIMO Localisation

Demand for location-based services is expanding. Statutory positioning requirements and the need for improved geolocation in urban, indoor and obscure environments are the drivers for this research. Mobile network based location schemes need to reduce dependency on calibrated antennas and take advantage of simple and inexpensive components as well as massive MIMO capabilities. Massive-MIMO systems employ a very large number of antennas (e.g. 128 elements) to exploit spatial diversity of the channel, allowing simultaneous use of time/frequency resources. Significant opportunities for localisation come from the possibility to use inexpensive, low-power and low-precision components, with greatly reduced complexity/cost in terms of antenna requirements and equipment calibration. Enhanced location in turn has the potential to provide significant benefits to MIMO-based systems, like reduced pilot contamination, reduced transmit power, improved resource allocation techniques, new handover strategies and the possibility of using the geolocation information for beamforming.

However many challenges exist and require investigation. Ray tracing simulations are being used to investigate Massive-MIMO location techniques. The need for line of-sight/non-line-of-sight (LOS/NLOS) identification has been confirmed. A scheme for LOS identification using Least-Squares Support Vector Machines (LS-SVM) machine learning has been devised, achieving greater than 90% classification accuracy. A corresponding NLOS mitigation technique has also devised been using the LS-SVM.

Student: Giovanni Ciurleo

Project: Passive Intrusion Detection Methodology in IoT Network Systems

Explosive development of IoT (internet of things) sensor devices has led to a proliferation of devices in all aspects of modern life. Current work has led to miniaturised devices that collect as much data as possible and send the data across the IoT network as quickly and efficiently as possible. Traditional security systems which are used to protect data and network devices are no longer adequate in the context of the IoT. This means that implementation in IoT devices using traditional security systems, has the trade-off of making the devices more prone to latency and has a detrimental impact on available resources in terms of bandwidth and efficiency so most suppliers do not use security on their devices. What this means is that since these IoT devices lack any form of security they provide a back-door to any connected systems.

This work attempts to resolve this issue by looking at malicious attacks in the same way a biological system is detected, operates and spreads, through the use of Social Network Analysis. Using this proposed methodology the system can be analysed to detect normal or malicious operation through its interconnections and other passively available data. In doing so, the detection methodology can predict when an attack is about to happen, how long until the system will fail during an attack and when the system is operating normally. This work provides a template for "weightless" security systems that passively interrogates the IoT network system, in such a way as to not alert an attacker or compromise the transfer resources required for efficient communication.

Student: Michael Dilmore

Project: Software Defined Networking and Converged Heterogeneous Networks

In recent years the demand placed on networks has grown exponentially. Applications have become increasingly data intensive and networking practices have also changed; virtualisation has made the Internet more dynamic and the shift to cloud computing moved data and applications off our hard disks and onto cloud based servers.

Software Defined Networking (SDN) is a new networking paradigm that hopes to solve the issues above by breaking vertical integration; the control frame is decouple from the data plane and placed it inside a logically centralised controller. Network switches become simple forwarding devices, programmable by the central controller. Applications run on top of the central controller (or Network Operating System) and perform operations such as setup and maintenance, routing, traffic engineering, policy enforcement, and network security. Centralised network applications result in a more flexible and manageable infrastructure, which improves operational efficiency and helps foster innovation. SDN is thought to be a key enabling technology as part of a future converged infrastructure for heterogeneous networks.

This project investigates network control and management functionalities specifically for next generation radio access, optical core, and data centre networks, with a view to identifying requirements for the coordination, orchestration and unification of their control using Software Defined Networking (SDN) techniques.

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Student: Douglas Harewood-Gill

Project: Abstraction of Heterogeneous SDN Utilising Artificial Intelligence Methods to Enhance Integration & Performance

Current networks that rely on a distributed control architecture are approaching the point where they are unable to cope with the increasingly high traffic and Quality of Service (Qos) requirements being demanded by everyday users and applications. Bell Labs have predicted that monthly global internet traffic will increase from 3,600 petabytes measured in 2006 to a predicted 80,500 petabytes by 2016. This exponential increase is expected to continue and as such, new networking techniques are required to keep pace with the rate of grow.

A possible solution is Software Defined Networks (SDN) where a centralised control approach separates the Forwarding and Control Planes in a network device in which the Network Operating System (NOS) can be used to control many individual network devices at one time.

Using this SDN structure, the research is focused on using ML and AI techniques to create an abstraction layer for heterogeneous technologies with the goal of being able to recognise new and previously undiscovered network devices technologies and configurations and supplying information about the network device to the SDN controller for greater network efficient and smarter forwarding decisions.

Student: Ioannis Mavromatis

Project: Wireless Connectivity in Autonomous Vehicles

Autonomous vehicles are expected to become an effective solution to reduce the huge number of casualties caused by road accidents and increase efficiency. They are vehicles capable of driving themselves without any human supervision. This requires them to carry a large number of sensors and exchange raw data streams via high data rate and minimum latency communication links. These streams can be processed later to identify the best navigation path and perform complex manoeuvres such as parking or obstacle avoidance.

They are capable of sensing the surrounding area for other cars, road signs or obstacles and interpret the information collected, to identify the best navigation path, or perform emergency avoiding moves. The adoption of this new technology, will solve many of the aforementioned problems, improve peoples' everyday life and will revolutionise the idea of travelling.

To maximise safety for the ecosystem of self-driving vehicles and pedestrians, it is mandatory to achieve ultra-reliable and robust Vehicle-to-Everything (V2X) communication. A conjunction of various wireless standards (Heterogeneous Network) as well as a multi-layer classification of the exchanged data streams seems like a viable and durable system solution to the challenge.

During this project, various technologies related with vehicular networks will be investigated having as the main focus to enhance the safety applications and later improve the performance of the infotainment applications as well. Real world experiments, as well as simulated scenarios will be evaluated under the Intelligent Transport System (ITS) and the millimetre waves frequency bands and algorithms will be designed to solve the problems that will be observed with respect to the Medium Access Control (MAC) and the Network Layer of the Vehicular Ad-Hoc Networks (VANETs).

Student:	John McInnes
Project:	Increasing Physical Layer Security using Novel EM Fields

Physical layer security considers the problem of communicating across a medium shared with a node whose behaviour is considered a threat to the link's confidentiality, integrity or availability. Popular security protocols such as IPSec offer no assurance below the network layer, incur significant overheads and are often sub-optimal in an information-theoretic sense.

This project will combine the significant analytical progress in physical layer security research with novel EM field techniques which should, intuitively, increase link security. Well established results from information theory and detection theory, in particular Wyner's wiretap channel and Neyman-Pearson hypothesis test criteria, provide useful tools to characterise the probability of interception or detection of a link.

Existing literature mainly applies these results to a given SNR however the receive power at a threat node can be highly variable. Techniques such as Orbital Angular Momentum, Direct Antenna Modulation, Non-Diffractive Beams and Surface Wave transmissions are sensitive to many physical phenomena such as multipath, beam alignment, link distance, radiation pattern and the threat's receive array.

Challenges being addressed include benchmarking existing radiation patterns, developing a security metric framework, parametrising a valid threat model and creating an experimental set-up for validating results, particularly for scenarios which involve dynamic channel models.

Student:	Laurence Smith
Project:	Efficient Power Amplifiers for IoT Machine-to-Machine Devices

Machine-to-Machine (M2M) communications covers the wireless links between autonomous devices and is already a large part of the new and much discussed Internet of Things (IoT), although market analysts like Machina Research predict a worldwide market of several billion M2M devices (worth over a trillion USD) by 2020. A range of modern applications including factory automation and smart metering are enabled using large networks of small and relatively basic sensors with M2M communications capability. Power efficiency is key for M2M devices as they must function for multiple years using limited energy sources (i.e. small primary batteries).

The project will investigate how to best achieve efficiency with the design of Power Amplifier (PA) component in the transmitter. Architectures that complement the more unique requirements of M2M transmitters will be explored using a combination of RF circuit simulation and physical device measurement, so that M2M-tailored approaches to PA design can be suggested.

Student:	Jonathan Weissman
Project:	Stochastic Geometry and Wireless Networks

Point processes can be used to model the planar distribution of active transmitters in an ad-hoc wireless CMSA network. Instantaneously, it may be assumed that the competing transmitters are distributed as a homogeneous PPP and that fading follows a constant path loss law. The competing transmitters may then be assumed to possess some common sensing radius R. All nodes may also be assumed to be equipped with a continuous timer of uniform i.i.d. duration. A node transmits (becomes active) if and only it senses no other node before its timer expires. Under the previous assumptions, the Matérn Type III process models this distribution of active transmitters.

In the plane, as the PPP intensity tends to infinity, the jamming limit of a hard-core point process of exclusion radius R is the fraction of the plane occupied by the union of disjoint discs of radius R/2. The Matérn Type III jamming limit is ~54.7%. This is significantly below the planar packing density of $\pi/\sqrt{12} \sim 90.7\%$, which is achieved by the triangular lattice. Can a distributed, provably finite-time protocol be described that achieves a jamming limit somewhere between 54.7% and 90.7%?

The problem may be phrased as an asymmetric colouring problem. We wish to colour as many nodes from the PPP as possible, subject to the constraint that no such pair of coloured nodes lie within distance R of each other. By exploiting local node geometry (degrees under the R-disc connection model), we propose such a protocol.

First Career Destinations of Postgraduates

Vaia Kalokidou

has been appointed as a Research Associate at the University of Bristol and is investigating working on the EU H2020 5GPPP 5G-XHaul project.

Peter Bagot

has taken up a post as a Research Associate at the University of Bristol and is investigating Virtual Increase in Signal Analysis Bandwidth for Wideband Transmitter Optimisation.

Alex Kartun-Giles

is a Research Associate at the University of Bristol and has been awarded EPSRC Institutional Sponsorship to research Random Walks on Random Geometric Networks and the mathematical theories of one-dimensional superhighways of autonomous vehicles.

Divya Mohan

has been recruited by Renishaw plc as a Software Engineer in Test and Innovation.

Leo Laughlin

is working as a Research Associate at the University of Bristol. He is investigating Flexible Duplexing through EPSRC Impact Acceleration Award funding with u-blox.

Tom Kealy

has taken a post as Research Associate in Text Analytics developing geoparsing technology for the maritime industry - creating an AI which takes unstructured text and produces points/directions on a map to aid Mariners in navigation.

Our Supporters & Collaborators

How to Get Involved

Industry

We welcome proposals for research project topics that can be sponsored - through fully funded studentships, iCASE, and Case conversion awards. from industry (exisiting and new collaborators).

We are also keen to further develop the specialist training available to our students and ensure the provision of state-of-the-art test & measurement equipment. If you wish to become a partner in the Centre please contact Professor Mark Beach, Centre Manager (M.A.Beach@bristol.ac.uk).

Prospective Students

Applications from potential students are accepted from October each year for entry in the following September. Please contact the Admissions Tutor, Dr Simon Armour, (Simon.Armour@bristol.ac.uk) if you would like to discuss opportunities for study.

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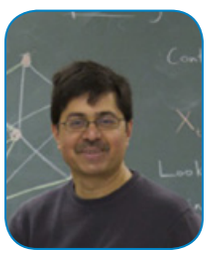

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