Cross-ICT priorities

Challenges and opportunities for the research community

EPSRC
Engineering and Physical Sciences Research Council

Introduction

The ICT capability theme includes UK research into computer science, user-interface technologies, communications, electronics and photonics; the common thread being the contribution of these fields to the development of information and communication technologies (ICT).

Through our cross-ICT priorities we recognise the context in which ICT research is supported by the theme; what needs to happen to ensure the UK's research capability remains world-class, and gives the UK the maximum potential benefit. These priorities arose from consideration of how the landscape we support should evolve. In determining the focus of the priorities, we took account of the current nature of the EPSRC portfolio, the challenges that need to be addressed, the opportunities that can be taken, and the expectations this places on certain research areas and researchers.

Three of the cross-ICT priorities relate to cross-cutting technological and societal challenges that can only be fully addressed by drawing on the expertise and efforts of researchers from across the ICT research landscape. The remaining two priorities champion new, innovative approaches and a collaborative culture of working across traditional discipline boundaries to foster new research directions and increase the potential for greater impact from research. Researchers should consider the context that underpins and has led to each priority, what the challenge represented by the priority influences the research they do, and how they can contribute to the aim of the priority being addressed.

New and emerging areas in ICT

EPSRC encourages and supports researchers who wish to work on truly transformative concepts and technologies within and beyond the currently recognisable ICT space.
To be 'new and emerging' an area needs to comprise something more than an advance, however significant, within an established field. It must be genuinely disruptive, offering real potential to significantly alter current practice in research or industry. Broadly speaking, we might see new and emerging ideas in the ICT portfolio arising in two ways: grown within the theme or translated into it from other themes.
Examples of translational new and emerging areas for ICT could include Quantum Information Processing (QIP), or carbon-based electronics. QIP is predominantly treated as a physics issue at present, with some chemistry and materials science in its implementation, but as a fundamentally information-related subject with immense practical implications it should also be the domain of ICT researchers. Similarly, much research into carbon-based materials such as graphene is justified on the basis of its asserted (but unproven) potential to offer a quantum leap in electronics performance. ICT researchers will be the implementers of this technology and ought to be involved in its development. To date, only a small number of applications have been received, and proposals supported, which contribute to this priority. More encouraging, however, has been the acknowledgement amongst the research community that efforts to contribute to this priority require a higher degree of research novelty, which we are always keen to foster through all of our funding mechanisms. In addition, the ICT theme is working with other themes within EPSRC, experts in academia, and research users to facilitate the emergence of new areas into the ICT themes portfolio.

Towards an intelligent information infrastructure

The current information infrastructure is being strained by a deluge of data and the ever-increasing requirements to support bandwidth-hungry applications, enhanced security measures and the increasing mobility of computing. A future information infrastructure needs to intelligently manage massive amounts of data, ensure efficient communications and exploit the content and information that will be available.

With the increasing emphasis on ubiquitous computing and the surge of information it generates, there needs to be smarter computing architectures, sustainable networks and secure storage solutions, as well as the capabilities to understand and efficiently manage the content within existing data. To manipulate, understand and use data and content to the maximum potential and encompass this in an intelligent framework is a considerable research challenge that has been recognised through dialogue with the research community via the theme days, networks, managed programmes and workshops.

This priority has the potential to build new research that could address the treatment of large data-sets, performance of digital services and exploring emerging technologies for low power, high speed, high density, low cost memory and storage solutions, which replace existing methods. Such considerations span many areas of ICT from Networks to Mobile Computing, Artificial Intelligence to RF Devices and from Information Systems to Image and Vision Computing.

There are key opportunities for pioneering research challenges that could resolve the telecommunication bottleneck and address the deluge of data and deliver understanding from information that would have high impact for individuals and future society, with links to application areas and societal challenges such as Healthcare, Cyber Security, Digital Economy, Cloud Computing and Ethics.

Recent progress

In December 2012, EPSRC held an ICT community workshop to encourage discussion around the Towards an Intelligent Information Infrastructure priority and identify some of the challenges presented by the priority for a potential call. Researchers from across the ICT community identified two major cross-cutting challenges – 'The Communications Bottleneck' and 'Extracting Understanding from Data'. The workshop also highlighted a need for cross-disciplinary working across most of the ICT research landscape, and beyond.

Taking into account the discussions held at the workshop, the ICT theme released a call in May 2013 – A Step Towards an Intelligent Information Infrastructure – that sought to address the highlighted challenges by asking researchers to address two or more sub challenges identified by the workshop; including Protocols for a 21st Century Internet, Energy Efficient Communication and Data Systems, Building Context and Content Aware Networks, Extracting Understanding from Data, and Seamless Mode-adaptive Communications.

EPSRC also continues to encourage researchers to contribute to this priority using other funding mechanisms, including standard mode.

Visible light communications

Professor Harald Haas, of the University of Edinburgh, holds an Established Career Fellowship from the ICT theme. The Fellowship proposes an adventurous programme of research into the many exciting possibilities presented by Visible Light Communications, 'Li-Fi' (Light-Fidelity), a term coined by Professor Haas in his July 2011 TED talk, now widely used in the context of broadband optical wireless communication systems. One of the many challenges to be tackled is the problem associated with the continued increase in the amount of data which needs to be transmitted and stored. Cisco forecasts a ten-time increase in global mobile data traffic within five years and much of that will be video traffic. Over one billion unique users visit YouTube every month, uploading more content than the three major US TV networks have broadcast in the last 60 years; that's 72 hours of video uploaded per minute. This massive demand will only increase and current wireless technologies may not be able to keep up because of the scarce radio frequency (RF) resources.

Harald explains that he addresses these problems through his Fellowship by the application of Li-Fi into future wireless networks. He notes that the visible light spectrum has 10,000 times the bandwidth of the entire RF spectrum. It is unregulated, safe and unused. He adds that the major contribution to the increase in spectral efficiency in cellular networks is the small cell concept. According to data from Ofcom, there has been a 2,700-fold increase in spectral efficiency over the past 50 years as a result of this. The optical 'attocell' network (coined by Professor Haas), where the light bulb functions as an optical access point and at the same time as an illumination device, can achieve up to 1,000 times improved spectral efficiency per unit area compared to small cell RF networks because light does not penetrate through walls. As a consequence, interference (the main limiting factor in RF networks) is largely reduced. Harald explains that his project "will develop hybrid systems where optical attocell networks and future RF networks are seamlessly integrated".

Harald's Fellowship work also demonstrates a strong contribution to the Working Together priority, necessary for all fellowship applications in ICT. As Harald puts it: "To me, it seems almost impossible to generate large impact in communication systems without engaging across communities. It is the optimised interplay between devices, transmission media, signal processors, techniques and algorithms, protocols, and data storage that leads to the most efficient communication systems. Clearly, no single field can achieve this. Therefore, in my opinion, the goal must be to convince many stakeholders across disciplines of the benefits of a grand vision and to take them along the same path which then naturally will become a joint vision."

Many-Core architectures and concurrency in distributed and embedded systems

With single core processors at or near their maximum clock speed, it is widely recognised that novel architectures are required. These should deliver increases in computational power within a restricted energy envelope; necessary to enable future electronic devices.

There has already been a shift by industry to multiple cores but there are aspirations to move further, to many cores.

A wealth of opportunities exist if an architecture containing hundreds or thousands of cores can be properly exploited, but massive parallelism raises challenges in both the hardware and software research areas. For example, the rate of increase in core numbers is likely to be such that scalable hardware and software approaches will be needed that are independent of the degree of parallelism.

Recognised globally as a key topic, the UK can contribute most effectively to the larger parallelism agenda through its inherent strength in embedded systems research.

Computation shared over multiple elements also presents particular challenges in distributed systems; another UK strength.

With many (often mobile) devices per person with almost permanent connectivity, it can be seen that there has been a dramatic change in the way people use technology. Challenges to full exploitation of both embedded and distributed architectures include heterogeneity and concurrency issues, while energy consumption will remain a foremost concern in research.

EPSRC is encouraging research that aligns to this theme, and which provides new insight in architectures, compilers, languages, verification, and models of computation. It is important that researchers from across the ICT disciplines and beyond work in concert with each other, approaching research questions from various angles while contributing towards common goals.

Recent progress

In March 2012 researchers from across the ICT portfolio attended a workshop to identify challenges which lie underneath this priority and help inform the evolution of the EPSRC strategy over the 2011-2015 Delivery Plan. The outputs of the workshop were published as a report, available on the EPSRC website. A number of challenges were highlighted, but throughout the day it was observed by the delegates that for true system-wide solutions to issues such as energy consumption, reliability and performance, researchers at different levels of the system stack need to work together. This requires transparency between layers, consideration of appropriate levels of abstractions and possible tool development.

Taking into account the outcomes of the workshop, a call for research proposals – Systems Approaches to Distributed and Embedded Architectures – was launched in June 2012, supporting research enabling cross-layer or end-to-end system considerations. EPSRC also continues to encourage researchers to contribute to the Many-Core priority using standard mechanisms – several Fellowship awards and Programme grants have been supported that contribute to the priority as a result.

M3: Managing Many-Cores for the masses

Dr Timothy Jones is an EPSRC Early Career Fellow at the University of Cambridge. His Fellowship focuses on the challenges of automatically obtaining high performance and energy efficiency from future microprocessors, whilst the underlying components become more unreliable.

The advent of multi-core processors has meant that application developers have had to start writing software with parallelism in mind. Future many-core systems will contain tens or hundreds of specialised processing elements integrated within a single chip. However, transistor reliability is decreasing rapidly and software programmers will soon have the additional burden of identifying where on the processor their code should run to obtain energy efficient, as well as correct, execution. Dr Jones says,

> My research is developing automatic schemes to tackle energy efficiency, reliability and performance across the hardware/software boundary. These techniques will enable continued increases in computing power, while leaving programmers free to develop the innovative applications of the future.

Photonics for future systems

EPSRC encourages research proposals that aim to carry out leading-edge photonic material and device research. Researchers need to be cognisant that to have greatest impact, these devices ultimately need to be able to be incorporated into photonic systems.

Technology associated with the main disciplines within ICT is increasingly converging as all aspects of data input, information processing and transmission become embodied in systems. This 'systems approach' to ICT research has not been well represented in the EPSRC portfolio in the past. Photonics underpins a myriad of novel science and technology areas and is recognised as a key enabling technology in many future ICT systems. Taken together, these factors increase the importance of a systems approach to photonics research, as has been recognised by the research community through EPSRC-supported workshops and theme days.

In order to show good alignment to the priority, it is expected that researchers will be able to articulate the overall system they intend their device to contribute to, and to demonstrate that the requirements of such a system have been considered. This will require greater inter-connectivity of the community, both within photonic materials and devices, and with researchers in other fields. EPSRC is particularly keen that the community consider its future relationships with researchers in the areas of electronics, communications and software engineering; though this priority allows for applicants to collaborate with any other researchers applicable to strengthen the required systems approach.

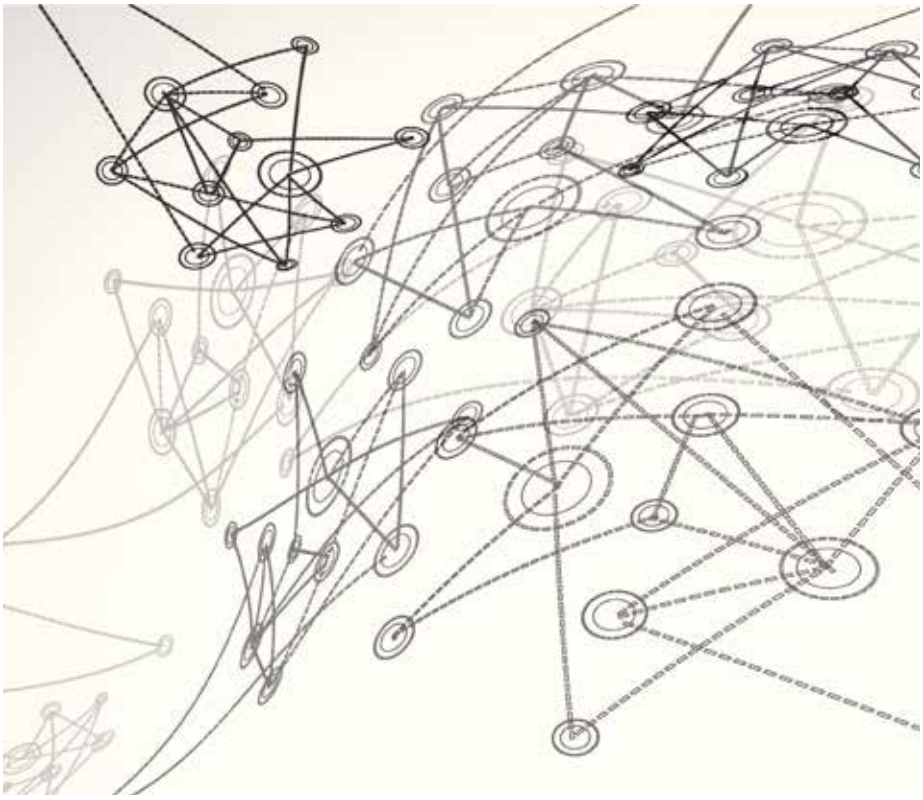
Recent progress

Following on from a series of discussions in 2009 and 2010, including the Photonic Materials and Devices Theme Day, Communications Theme Day, Electronic Materials and Devices Theme Day and Photonics Systems Workshop, it was clear that a systems approach to ICT was not well represented in the UK academic research community in a way that maximised benefit for the UK. At present, only a small number of proposals that are considered to be contributing to this priority have been received, and supported, through standard mode. The ICT theme is currently reviewing what is happening and encouraging adherence to the spirit of this priority. As part of this review process, ongoing discussions between EPSRC and key members of the community are taking place, which will be used to inform future interactions with the research community.

Transforming the internet infrastructure: The photonic hyper-highway

With continued growth in transmitted data volumes on all media, there is a widely recognised and urgent need for more sophisticated photonics technologies to forestall a 'capacity crunch' in the medium term. Professor Sir David Payne, of the University of Southampton, is leading a six-year project that focuses on the challenge of transforming the physical infrastructure underpinning today's networks into an energy-efficient, ultra-high capacity ICT infrastructure able to connect people and businesses seamlessly everywhere. They are addressing this challenge by developing disruptive component technologies and network concepts to enhance communications infrastructure, avert network gridlock and reduce energy consumption of communications systems.

Working together



In one sense, Working Together is not new. This priority exists to help realise a long-standing desire commonly expressed by researchers in ICT: to do something truly new, or take a step away from the usual focus of their work. Collaboration between researchers, cross-fertilisation of concepts and consideration of other perspectives in research are just some of the aspects of 'Working Together' that have been highlighted to us during engagement with researchers and users in ICT.

Mapping our portfolio highlights dependencies between areas and convergences occurring between them. Every year brings more and more significant ICT challenges, which present real opportunities for researchers from across the landscape. Activities which promote exchange of knowledge between upstream and downstream research enhance the potential for impact from the portfolio. This makes a real difference to the shaping of UK capability and is essential if we are to maintain a healthy research base.

EPSRC's Challenge Themes of Digital Economy, Energy, Healthcare Technologies and Manufacturing the Future will not realise their full potential without contributions from those at the cutting edge of ICT. Researchers will need to connect with those outside their own immediate area to contribute to these themes and to incorporate into them their growing awareness of ethical implications, societal factors and developments in other research areas.

Recent progress

Already, about a third of the proposals we receive address the Working Together priority in some way. As an applicant you should feel confident in referring to it in the proposals you send to us, and in using it to help guide the resulting research. As a reviewer you can rest assured that we are willing to support this kind of work.

ICT Fellowship applications are now expected to demonstrate the way in which they will contribute to the aims of the Working Together priority. Our Fellowship panels are consistently impressed with the positive response they have seen to this requirement – this is a real endorsement of the benefits of Working Together. Programme Grant applicants are asked to explain how their projects will be more than just a large grant. Much of what they say in response relates to 'Working Together'. As a result our most significant investments often contribute to the priority. Building on this, we are now encouraging researchers in the early stages of their careers, as the next generation of ICT leaders, to consider this priority when preparing their First Grant applications to EPSRC.

Efficient Algorithms for Mechanism Design Without Monetary Transfer

Piotr Krysta of the University of Liverpool and David Manlove of the University of Glasgow are working together on a project funded through EPSRC's standard mode. Building on more than a decade of collaboration, the Efficient Algorithms for Mechanism Design Without Monetary Transfer project will produce better ways of solving matching problems. These arise when trying to assign agents to commodities in optimal ways, but where financial considerations are not paramount. Examples include matching kidney patients and donors, and assigning junior doctors to hospitals. Their project addresses the Working Together priority in two ways: by bringing together researchers in computer science and economics, and by exploiting the results through collaborations with the NHS.

From theory to practice: putting HCI frameworks to work

Stuart Reeves is an EPSRC Early Career Fellow at the University of Nottingham. His fellowship will investigate and bridge the gaps between Human-Computer Interaction (HCI) theory and the practical realities of designing and building interactive technologies. It will produce new ways to weave HCI theory into practice, feed experiences from practice back to theory, and enhance methods of working together across disciplines and sectors. He will develop ways to bring the wealth of knowledge from previous work in HCI frameworks into practice and application more readily, reaching those working within HCI research and those outside who are nonetheless impacted by HCI issues.

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