COMPUTER SCIENCE
DATAVETENSKAP

ANNUAL REPORT 2018

COMMITTED TO EXCELLENCE IN COMPUTER NETWORKING,
SECURITY AND PRIVACY, AND SOFTWARE ENGINEERING

Contents

Foreword

Karlstad University is one of the youngest universities in Sweden. This makes us a little more adventurous. We see it as our role to challenge the established and explore the unknown. It is our ambition to contribute to the development of knowledge both at the international, regional and individual level. Underpinning all our teaching and research is a close dialogue with private companies and public organisations. We can thus offer one of the more inspirational university environments in the country.

"Computer Science provide education and research with a focus on distributed systems and communications, privacy and security, and software engineering. Our research is well established in the International research community and students are attracted to our educational programmes.

During 2018, the environment has continued to evolve and expand—new talented employees have been recruited, existing staff have been promoted, new external funding have been attracted, and new courses have been developed and provided.

We are happy to share our successful year with you through this annual report!"

Stefan Lindskog, Head of the Department of Mathematics and Computer Science.

Our mission

Computer Science is committed to being internationally excellent in research and education with a focus on distributed systems and communications, privacy and security, and software engineering. We will reinforce, extend, and diversify our strengths in collaboration and innovation, while striving to become recognised for addressing critical, scientifically important problems.

Staff

One of the factors behind the success of Computer Science is the international environment with staff from many parts of the world. The differences in experience, knowledge and perspective generate new knowledge. In 2018 we continued to grow and more talented staff members were recruited. Since 2012 the number of staff members have more than doubled, partly thanks to the increased internal support we have been given as one of the appointed excellent research groups at Karlstad University.
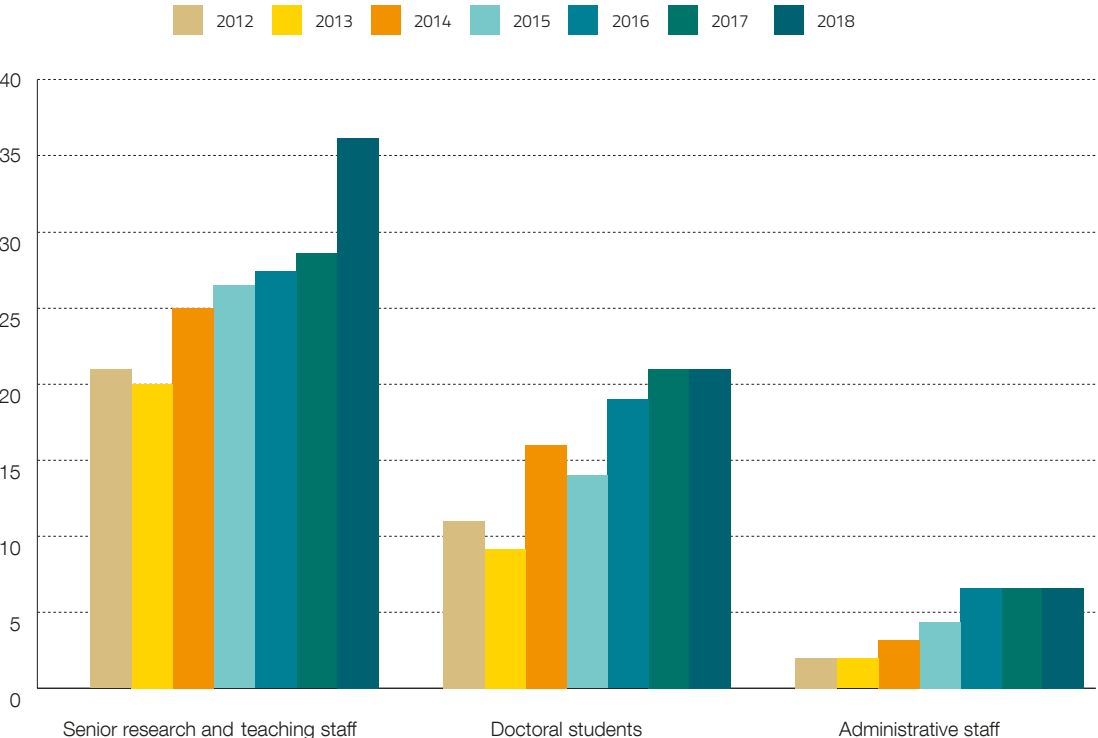
Diversity
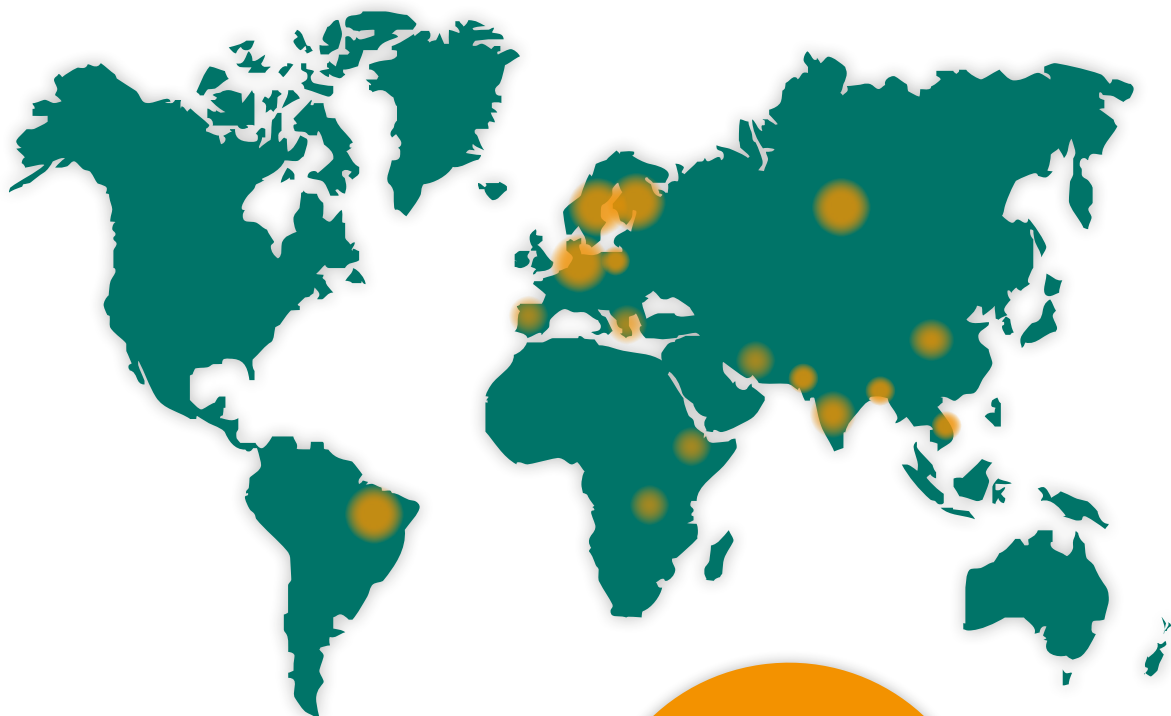
Our employees come from
eighteen countries around
the world and represent
four continents

Education

Karlstad University is renowned for providing high quality training in several professional areas. Computer Science is one of them. We provide students with the opportunity to be a part of forming the technology and society of tomorrow and offer education on both basic and advanced level.

In Computer Science, the education, as well as the research, is mainly focused on distributed systems and communications, privacy and security, and software engineering.

"The students in computer science have good opportunities to get practical experience from interaction with their future employers as well as with research. This is made possible by our strong connections with the local industry as well as by our close conection between research and education. The practical cooperation is carried out through student projects as well as in practical assignments in various courses.

We are constantly developing and refining our courses and study programmes. In recent years we have restructured our programmes to provide a better combination of the initial courses in programming and to provide the students with a stronger foundation and better opportunities to tackle their studies later in the programmes. A Bachelor programme in computer science was developed during 2018 and will be launched during 2019.

During 2018 we have also successfully launched the educational project on web-based courses for international positioning of strategic research profiles with a focus on IT-security. Moreover, we have designed a number of similar courses om current and future communication technologies."

Johan Eklund, Director of Studies.

Projects and collaboration

Development of a harmonized modular curriculum for the smart grid (DAMOC)

DAMOC is an ERASMUS+ funded project that aims to develop master's level programmes at universities in South Africa and Tanzania, with a focus on smart grids. Computer Science, together with Technische Universität Dresden, contributes with expertise and development of courses and course material on information security and privacy linked to smart grids.

Cooperation industry and IT students (SNITS)

SNITS is a collaboration group associated with the IT programmes at Karlstad University that offers a variety of activities to promote meetings between students and industry. SNITS arranges study visits, guest lectures, lunch meetings, mentorship programmes, practical placements and degree projects. It is a great opportunity for students to get in touch with the industry during the studies.

New flexible cutting-edge courses promote lifelong learning (WISR16 and WISR17)

Karlstad University has invested in developing several flexible and international cutting-edge courses. In 2018 one course within the computer science field was launched and two more were developed to be launched in the spring semester of 2019. The courses are offered in a flexible online format. Participants choose whether they want to take a course for credits, or whether they want to take an open course with no entry requirements or assessment. The courses are based on state of the art research, and have been developed in close cooperation with a number of partners from the business sector. The WISR16 and WISR17 projects are both funded by the Knowledge Foundation.

Study programmes in Computer Science

In 2018 there were four programmes to choose from when majoring in Computer Science.

Bachelor of Science in Engineering: Computer Science, 180 ECTS credits
Study Programme in IT Design: Software Design, 180 ECTS credits
Master of Science in Computer Engineering, 300 ECTS credits
Master Programme in Computer Science, 120 ECTS credits

Research

Computer Science constitutes one out of two excellent research profiles at Karlstad University. The establishment of excellent research profiles has been an important part of the university's strategic efforts to strengthen and profile its research. As such, Computer Science plays a leading role in the university's ambition to contribute research that is both of the highest academic standard and that hold great significance for society.

"Research within computer science at Karlstad University is primarily focused on distributed systems and communications (DISCO), privacy and security (PriSec), and software engineering (SERG).

Our research environment has expanded substantially in the last couple of years, both in size and in quality, and this trend has continued in 2018. Our DISCO and PriSec profiles are already successfully established in the international research community and our SERG profile is starting to gain reputation.
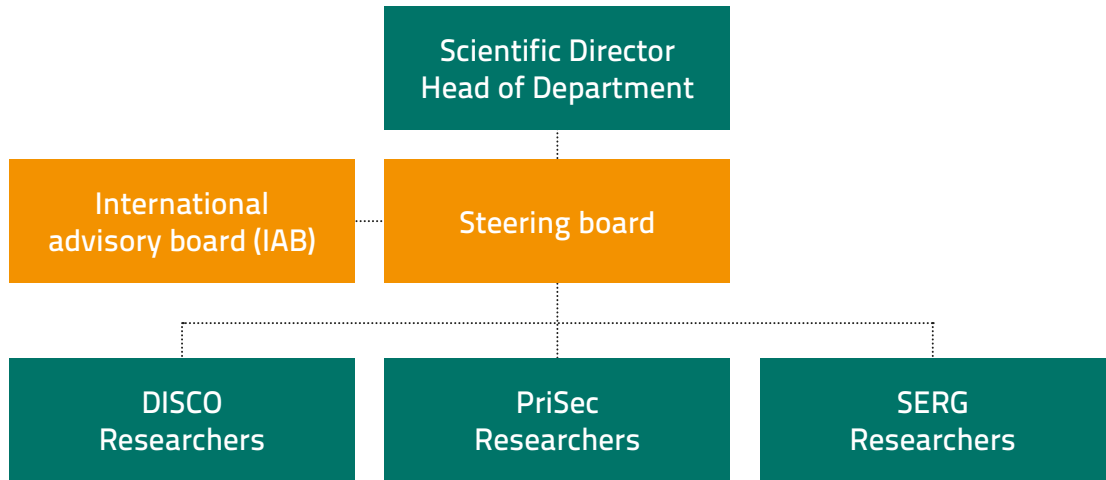
In 2018 we have successfully renewed and expanded our externally funded project portfolio, including the startup of two new prestigious H2020 projects. New national and international networks have been established and the amount and quality of our publications has stabilised at a high level. Our doctoral students also continues to make us proud, winning several awards during the year.

Through the dedicated efforts of our researchers we have generated important new knowledge, advancing the research frontiers and contributing towards the technology and society of tomorrow."

Anna Brunström, Scientific Director for the Computer Science Research Group.

Research organisation

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                    │   Head of Department     │
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│     DISCO     │       │     PriSec     │        │     SERG      │
│  Researchers  │       │  Researchers   │        │  Researchers  │
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Members of the Computer Science Research Group steering board

Anna Brunström (DISCO)
Professor

Simone Fischer-Hübner (PriSec)
Professor

Andreas Kassler (DISCO)
Professor

Stefan Lindskog (PriSec)
Professor and Head of Department

Lothar Fritsch (PriSec)
Senior lecturer and docent

Karl-Johan Grinnemo (DISCO)
Senior lecturer and docent

Sebastian Herold (SERG)
Senior lecturer and docent

Leonardo Martucci (PriSec)
Senior lecturer and docent

Javid Taheri (DISCO)
Senior lecturer and docent

Håkan Spjuth
Grants and Innovation Office (GIO)

International advisory board

An international advisory board (IAB), is connected to The Computer Science Research Group. The purpose of the IAB is to provide feedback on progress and future research directions.

The external feedback is important for us in order to strengthen our research environment and to continue our positive development.

The board consists of six external advisors:

- Hans Einsiedler, Senior Project Manager, Deutsche Telekom, Germany
- Kristin Fuglerud, professor at the University College of Southeast Norway and the Norwegian Computing Center
- Maritta Heisel, professor at Duisburg University, Germany
- Jukka Manner, professor at Aalto University, Finland
- Angela Sasse, professor at University College London, UK, and Ruhr University Bochum, Germany
- Christian Schaefer, Master Researcher, Ericsson Research, Sweden
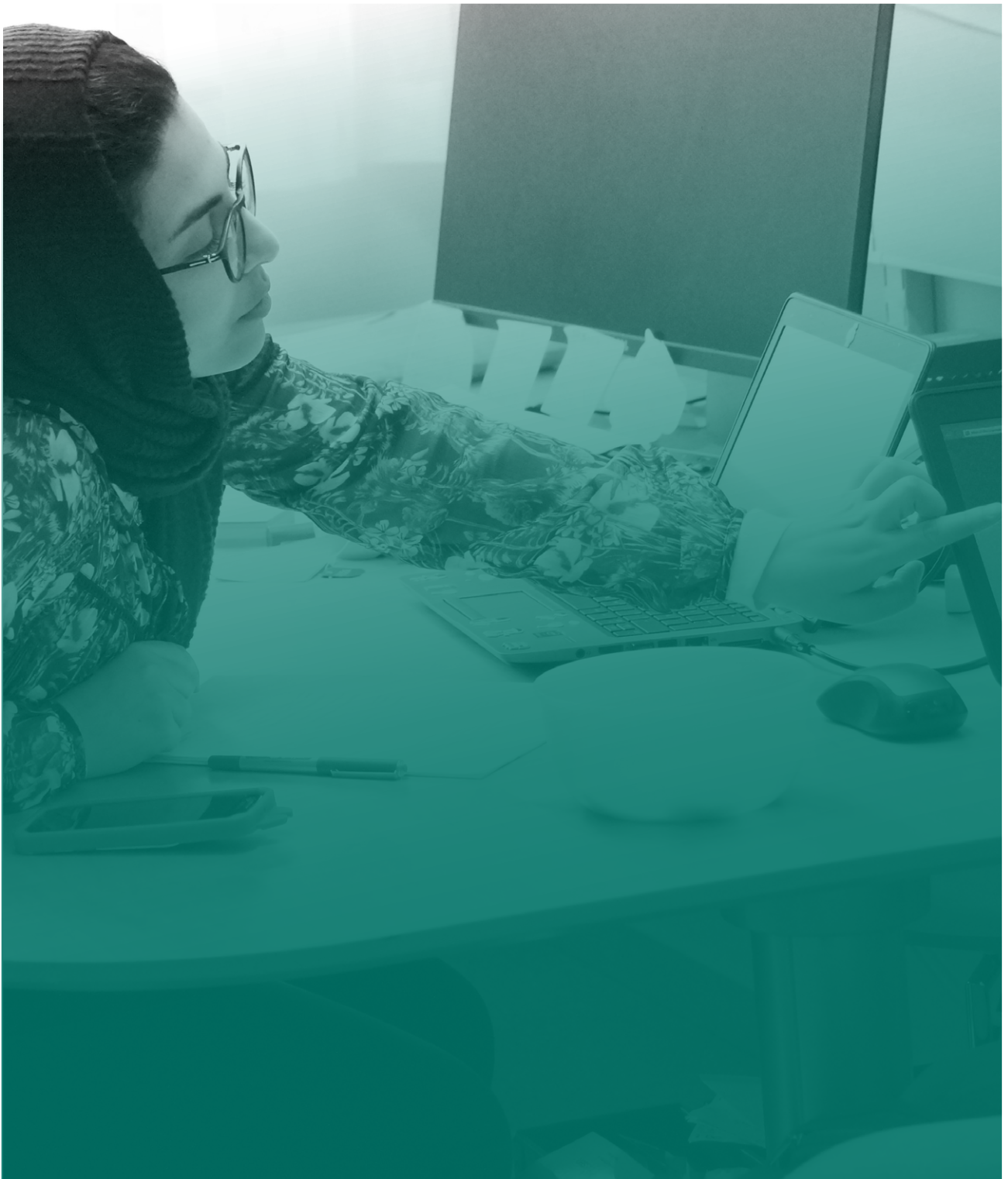
Research profiles

Research within Computer Science is based on a project and collaborative culture. Through interdisciplinary research between the three research groups as well as joint projects with external partners from both academia and industry we contribute towards tomorrow's technology. The research profiles are: Distributed Systems and Communications, Privacy and Security and Software Engineering.

Distributed Systems and Communications (DISCO)

Research within DISCO focuses on the development of multi-access solutions, techniques for low latency communication, cross-layer interactions and the design of future 5G wireless systems, including the use of NFV/SDN and cloud-based RAN and core networks. The research is carried out in close collaboration with industrial and academic partners and applies a combination of network measurements and traffic analysis, emulation, simulation and analytical modelling and optimisation techniques. Research on network security is carried out in collaboration with PriSec.

"Internet and mobile communication networks have become critical infrastructures of essential importance to society. Our research makes important contributions to the continued development of these infrastructures and their abilities to support new emerging applications. It helps the Internet architecture and it protocols evolve and it capitalises on the ongoing softwareisation and cloudification of networks to help deliver solutions for tomorrows mobile networks."

Anna Brunström and Andreas Kassler, research leaders for DISCO.

Privacy and Security (PriSec)

Research within PriSec focuses on privacy-enhancing techno-logies and network security whereas network security research is conducted in close cooperation with DISCO. Current research directions of members of the PriSec profile include but are not limited to: usability aspects of privacy-enhancing technologies, privacy and transparency in cloud computing, privacy metrics and languages, analysis and circumvention of censorship systems, privacy and security in health care, and network security.

"Addressing future cyber security and privacy challenges requires cooperation by academia, government and industry at national international level. PriSec has a strong profile in the participation and leadership of several European, national and regional research and innovation projects and networks in cyber security and privacy in cooperation with other universities, companies and authorities. Thereby it is contributing not only with high scientific but also societal impact."

Simone Fischer-Hübner, research leader for PriSec.

Software Engineering (SERG)

Research within SERG focuses on different software eng-ineering aspects, particularly on software architecture and software evolution. The research of SERG aims at developing methods and techniques to continuously preserve, improve, and adapt quality attributes of long-living software systems in order to allow such systems to be maintained and to evolve more easily.

"The costs associated with maintaining and evolving soft-ware are incredibly high – we want to change this in different ways. For example, we investigate how to detect and mitigate architectural degradation in software. In the REVaMP2 project, we apply such techniques to support the efficient migration to software product lines. And in the Digital Well project, we are going to apply our knowledge and skills in an e-Healthcare context."

Sebastian Herold, research leader for SERG.

Research projects

For us as a research environment, projects are one of the fundamentals. We address relevant issues and have managed to build important networks and alliances. We are also successful in attracting external research funding. We conduct projects of various types and include partners from academia as well as from industry and the public sector. The composition of our recent and ongoing projects is illustrated below. We also highlight a few selected projects from 2018.
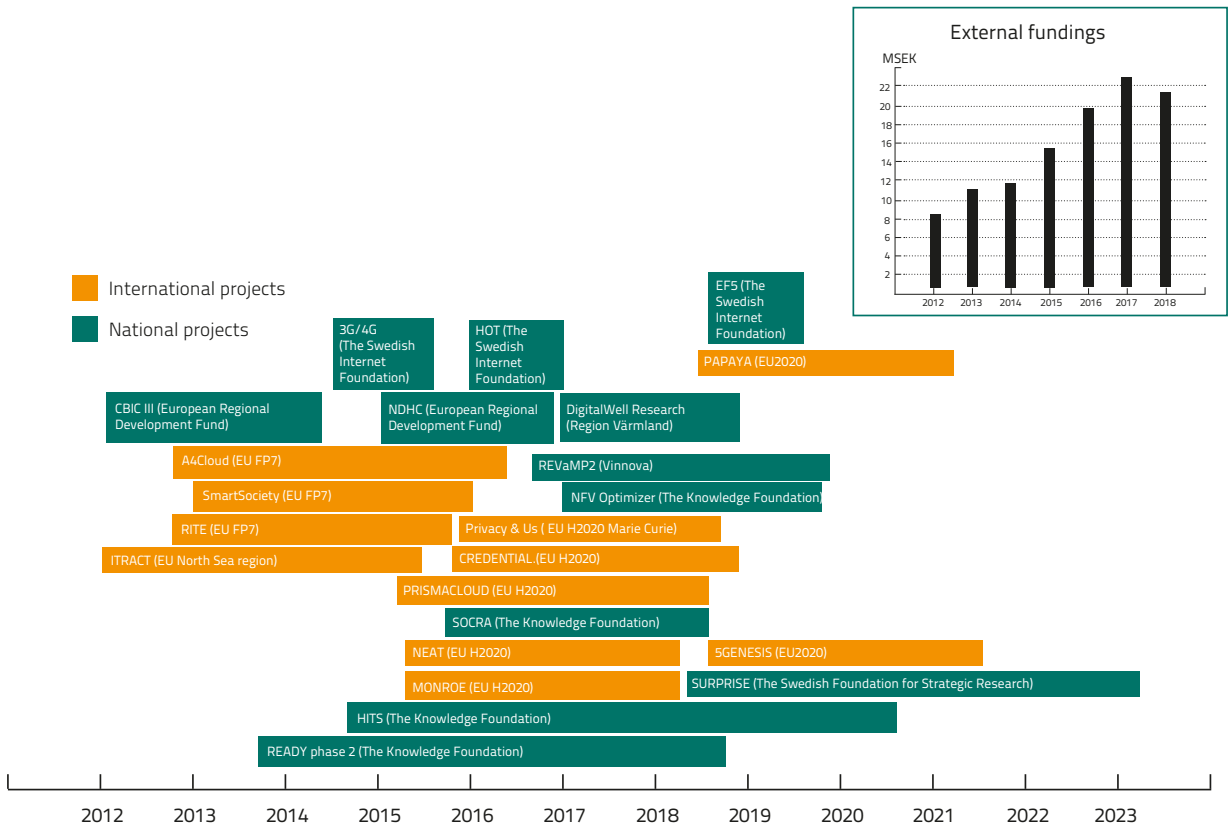
External fundings

*Only externally funded projects, running for a minimum of 12 months and funding staff salaries are included in the figure.

Software Defined Small Cell RAN Optimization (SOCRA)

With the current growth in user demand, future wireless access networks will have to offer capacity, which is many times larger than today's 4G networks. Since the capacity increase through advanced physical layer techniques is limited, one promising technique to increase capacity is to shrink cell sizes, also using mmWave. The goal of SOCRA is to research and develop architecture and algorithms for energy efficient capacity on demand 5G mobile communication networks combining robust network optimization algorithms, software defined networking and mmWave technology. SOCRA is a collaboration between Karlstad University, Huawei Technologies Sweden, Gotmic and Bluewave. The project is funded by the Knowledge Foundation.

Privacy and Security Maintaining Services in the Cloud (PRISMACLOUD)

PRISMACLOUD is developing the next generation of cloud security technologies. The project brings novel cryptographic concepts and methods to practical application to improve the security and privacy of cloud based services and make them usable for providers and users. The main idea and ambition of PRISMACLOUD is to enable end-to-end security for cloud users and provide tools to protect their privacy with the best technical means possible - by cryptography. The project is funded by Horizon 2020, the EU Framework Programme for Research and Development.

DigitalWell Research

DigitalWell Research provides industry and public sectors with research on the developments of digital social security services focusing on the needs of its users. The goal is to create an innovative environment, where research, industry and public sectors may interact to develop new digital social security services. Services in education and healthcare are prioritised. At Karlstad University, Computer Science, Gender studies, the Grants and Innovation Office, Mathematics, Nursing, and the Service Research Center, are involved in the project. Computer Science contributes with research in relation to service quality in 5G, security and privacy in IT-based systems in healthcare, support for prototype development of software-based services and digitalisation.

> "Compare and Computer Science have been partners for many years. A close collaboration between students and businesses has always been the focus here. In the future we plan to extend this partnership into DigitalWell Arena, an innovation environment where we co-create of our future wellbeing. Computer Science research projects are vital to build strong key competence in the Arena, developing future e-health services, from a user and data driven perspective."

Magnus Bårdén, Managing Director Compare.

Publications

Computer Science continues to produce a significant number of high quality publications. New co-workers and research projects in combination with an extensive international network of partners are some of the key reasons. We are also working strategically to further increase the visibility of our research and the quality of our publications. Also this year our researchers were acknowledged by winning awards at different conferences.
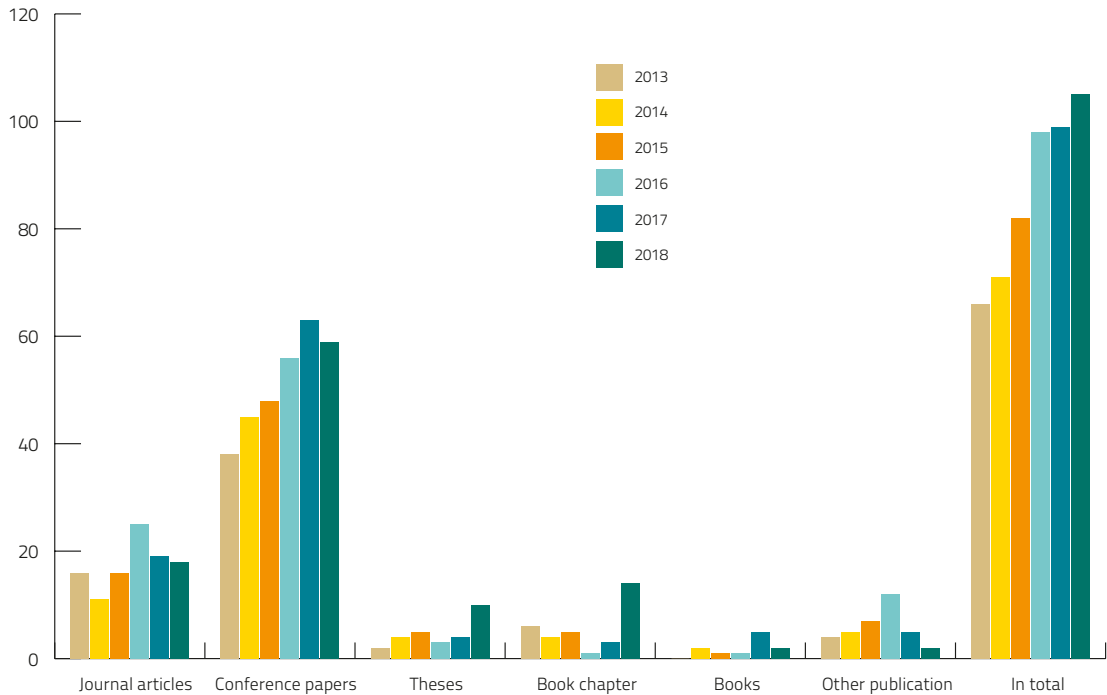
Awards showered on Computer Science

Several Computer Science researchers and students received prestigous awards at during 2018.

- Javid Taheri was the winner of the "Wilkes Award" from Oxford Academic for the paper "A Multi-
  -Objective Load Balancing System for Cloud Environments". The Wilkes Award is given once a
  year to the authors of the best paper published in the volume of "The Computer Journal" (CORE:
  Rank-A) from the previous year.

- Farzaneh Karegar and Simone Fischer-Hübner received the best paper award at the ACM Symposi-
  um on Applied Computing, SAC 2018, in Pau, France, for their paper "Helping John to make infor-
  med decisions on using social login", co-authored by Nina Gerber and Melanie Volkamer (University
  of Karlsruhe).

- Dejene Boru Oljira received the best paper award at Networks of the Future in Poznan, Poland. The
  paper, "MDTCP: Towards a Practical Multipath Congestion Control for Telco Cloud Datacenters", is
  co-authored by Karl-Johan Grinnemo, Anna Brunström and Javid Taheri.

- Michel Gokan received the best demo award at the IEEE Conference on Network Function Virtuali-
  zation and Software Defined Networks in Verona, Italy. The demo is based on the paper "Automa-
  ted Analysis and Profiling of Virtual Network Functions: the NFV-Inspector Approach", co-authored
  by Javid Taheri, Andreas Kassler and Marian Darula (Ericsson).

- Nurul Momen received the best poster award at NordSec in Oslo, Norway, for the paper "User Per-
  ception Analysis for Showing Personal Data Access as Privacy Implication Factor".

- David Johansson received the student travel award at the IEEE Conference on Network Function
  Virtualization and Software Defined Networks. The paper, "On the Energy Cost of Robustness and Re-
  siliency for Virtual Network Function Placement", is co-authored by Andreas Kassler and Javid Taheri.

"I note with great pride and admiration that awards have been showered on us
during 2018. These awards are further proof that our doctoral students and our
research is absolutely topnotch. Since I know how much hard work lies behind
such recognition, I can only agree with the motto Illis quorum meruere labores,
that is, 'for those whose labours have deserved it'."

Karl-Johan Grinnemo, Head of Subject.

Doctoral study programme

The three of our research profiles, DISCO, Pri-Sec and SERG, all host doctoral students. This year, we have also strengthened our research and research education in SERG with an additional senior lecturer.

"Our doctoral students are introduced to cutting edge research in distributed systems and communication, privacy and security, and software engineering. Since much of our research is funded through research grants and supported by industry, our students are given plenty of opportunities to collaborate with preeminent companies in their areas of study. Through our strong national and international networks our doctoral students build a large contact network. They also have opportunities to gain teaching experience at undergraduate level as teaching and lab assistants.

One notable success during this year was that the Swedish Higher Education Authority (UKÄ) decided that our doctoral study programme offers a high-quality doctoral education. We consider this a testament of our ability to provide high-quality research and research education that generates new knowledge, provides highly skilled know-how, and can address the research agendas of research users in industry, governments, and communities."*

Karl-Johan Grinnemo, Head of Subject.

Doctoral defence

Toke Høiland-Jørgensen: "Bufferbloat and Beyond: Removing Performance Barriers in Real-World Networks", 2018-11-23

Network performance has generally improved with time, but over the last several years we have seen examples of performance barriers limiting network performance. In his doctoral thesis, Toke investigates three areas where performance barriers are found: The bufferbloat phenomenon of excessive queueing latency, the performance anomaly in WiFi networks and related airtime resource sharing problems, and the problem of implementing high-speed programmable packet processing in an operating system. In each of these areas he present solutions that significantly advance the state of the art. All solutions are implemented as open source software, including both contributions to the upstream Linux kernel, as well as the Flent test tool, developed to support the measurements performed in the thesis.

Licentiate degree seminars

Farzaneh Karegar: "Towards Improving Transparency, Intervenability, and Consent in HCI", 2018-03-15

People share lots of personal data and leave digital trails on a daily basis. Controlling the proper use of data, people should be able to get information on the recipients, how their personal data are processed, by whom, and for what purposes. Offering transparency for achieving this type of control plays a significant role in the protection of individuals' privacy. The new General Data Protection Regulation (GDPR) also specifies that personal data shall be processed lawfully, fairly, and in a transparent manner. In her thesis, Farzaneh investigates how to design usable and user-centric tools and solutions which improve the transparency of personal information, help users to make informed consent, and empower them to keep control over their data by exercising their rights to intervene in the data processing.

Jonathan Vestin: "SDN-Enabled Resiliency in Computer Networks", 2018-05-11

In computer networking, failures, such as breaking equipment, cable cuts, power failures and human errors continuously cause communication interruptions. Such failures may result in dissatisfied customers, loss of product reputation, violation of SLAs and even critical failures in industrial systems. In his thesis, Jonathan focuses on resiliency in computer networks, i.e technologies which can repair networks, or redirect network traffic when some part of the network has failed. The thesis addresses the usage of SDN (Software Defined Networking) to provide resiliency in high availability networks.

Ala Alagra: *"The Wicked Problem of Privacy: Design Challenge for Crypto-based Solutions"*, 2018-06-11

Data privacy has been growing in importance in recent years, especially with the continuous increase of online activity. There is not a straightforward solution to the wicked problem of privacy. Enhancing data privacy is a complex challenge that requires many factors coming together: technological, legal, and human aspects. In their licentiate thesis, Ala has addressed that challenge and focused on human aspects of privacy enhancing technologies in an eHealth scope. The results yielded key HCI considerations as well as guidelines of different means for supporting the design of future solutions.

Giang Van Nguyen: *"Towards SDN/NFV-based Mobile Packet Core: Benefits, Challenges, and Potential Solutions"*, 2018-06-11

The mobile packet core (MPC) network enables the mobile operator to offer a new set of services to their users from external packet data networks (e.g., the Internet). However, to cope with the user demands and requirements of the upcoming fifth generation of mobile networks (5G), its architecture requires a radical change. Two promising technologies, namely Software Defined Networking (SDN) and Network Function Virtualization (NFV) have come into place. In his licentiate thesis, Giang identifies the benefits and main challenges of using SDN and NFV to redesign the current MPC network architecture, and then investigates different approaches to improve the scalability and performance of one of SDN/NFV-based MPC designs.

Dejene Boru Oljira: *"Telecom Networks Virtualization: Overcoming the Latency Challenge"*, 2018-06-13

Telecom network operators have adopted a cloud computing based service delivery model which enables the shared use of resources using virtualization technology and accelerates the deployment of new services. However, achieving carrier-grade network performance such as low response time, high data rate, and availability in the virtualized system is challenging. In his licentiate thesis, Dejene investigates the impact of virtualization on network performance, and the design of scalable multi-path data transport protocol for telecom datacenters to overcome the challenges.

Nurul Momen: *"Towards Measuring Apps' Privacy-Friendliness"*, 2018-09-07

Today's phone could be described as a charismatic tool that has the ability to keep human beings captivated for a considerable amount of their precious time. Users remain in the illusory wonderland with free services, while their data becomes the subject to monetizing by a genie called big data. Poor means to observe and to assess the consequences of data disclosure causes hindrance for the user to be aware of and to take preventive measures. In his licentiate thesis, Nurul argues that app behavior analysis yields information which has the potential to increase transparency, to enhance privacy protection, to raise awareness regarding consequences of data disclosure, and to assist the user in informed decision making while selecting apps or services.

Ricardo Santos: *"5G Backhauling with Software-defined Wireless Mesh Networks"*, 2018-11-22

Future 5G networks will promise ultra-fast internet access speeds with low latency, which can be achieved by densifying the deployment of a large number of small cell base stations. As it is not feasible to connect all small cells to the core network through a fibre-cable connection, an attractive solution to form a backhaul relies on the usage of millimetre-wave (mmWave) wireless connections. To manage and configure this wireless backhaul, the principles of software-defined networking (SDN) can be used, where all the decision-making processes are done by a centralized control entity. In his licentiate thesis, Ricardo explores how SDN can benefit the configuration of a wireless backhaul composed by multi-gigabit mmWave links.

Agnieszka Kitkowska: "Advancing Models of Privacy Decision Making: Exploring the What & How of Privacy Behaviours", 2018-12-11

The growing dependency on information technologies requires people to make privacy-related decisions on a daily basis. Potential consequences of such choices are rarely taken under consideration, which may result in poor privacy decisions and increased risk. However, when asked directly people express high concerns about digital privacy. In her licentiate thesis, Agnieszka investigates such dissonance between attitudes and behaviors by a thorough examination of the privacy decision-making process, focusing on different factors that influence the decision-maker. Such knowledge is essential to advance current technology and build solutions increasing privacy awareness and supporting informed decisions.
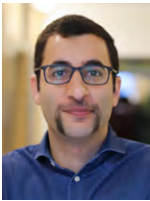
Kyoomars Alizadeh: "Towards Seamless Live Migration in SDN-Based Data Centers", 2018-12-19

Live service migration is the movement of a process/application between different physical servers while it is still running and providing service. The ability to live migrate services has significantly improved the flexibility of modern data centers and is known as a promising solution for data center administrators to achieve a wide range of objectives. Ideally, live service migration ought to be fast and seamless which means the service migrates between two servers within minimal time and without interrupting the connectivity of running applications and degrading the quality of service. In his licentiate thesis, Kyoomars provides solutions which contribute to decreasing the time needed to conduct live service migration.
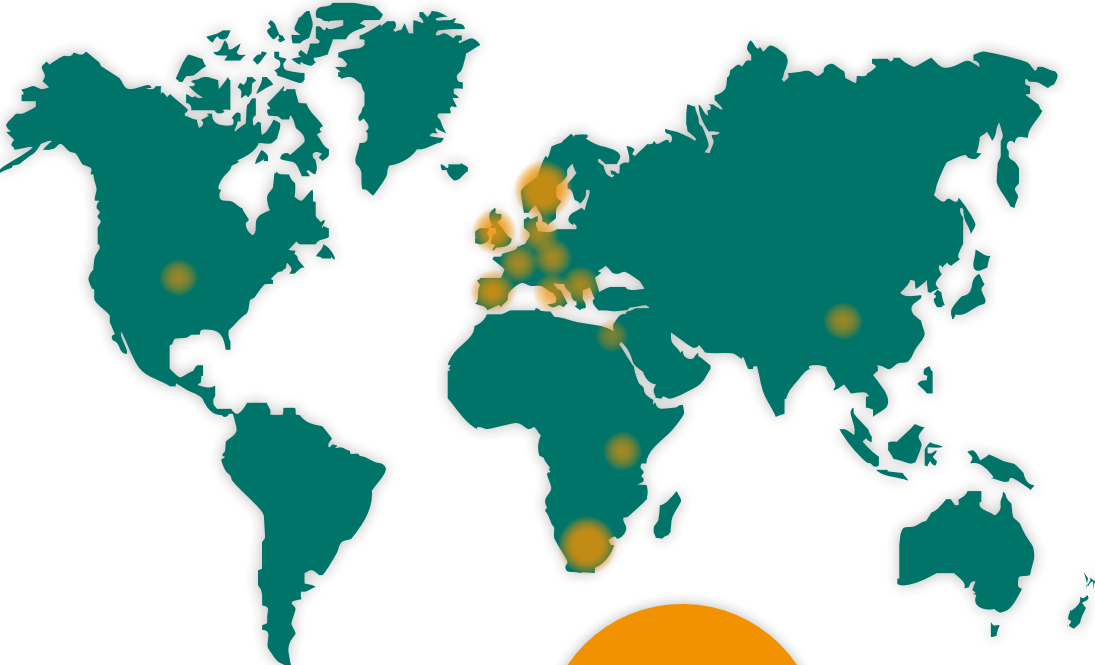
Partners

Our partners come from twenty countries around the world

72 partners come from industry

39 come from academia

Commissions of trust (selected)

Conference organization

- The International Symposium on Computer-Based Medical Systems (IEEE CMBS), June 18-21, Karlstad, Sweden (Lothar Fritsch, Finance chair, organizer)

- International Conference on Complex, Intelligent, and Software Intensive Systems (CISIS 2018), July 4-6, Matsue, Japan (Javid Taheri, Track Chair)

- IEEE Seventh International Conference on Communications and Electronics (ICCE 2018), 18-20 July, Hue Imperial City, Vietnam (Javid Taheri, International Steering Committee)

- IFIP Summer School 2018 on Privacy and Identity Management, August 20-24, Vienna, Austria (Simone Fischer-Hübner, General Co-Chair)

- Networking Architectures and Paradigms for ITC 2018, September 11-14, Vienna, Austria (Andreas Kassler, TPC Area Chair)

- The International Science and Technology Conference: Modern Network Technologies (MoNeTec 2018), October 25-26, Moscow, Russia (Javid Taheri, Program and Organising Committee and a keynote speaker)

- IEEE Conference on Network Function Virtualization and Software Defined Networks (IEEE NFV-SDN 2018), November 27-29, Verona, Italy (Andreas Kassler, Demo Chair)

Boards and scientific advisory assignments

- Scientific Advisory Board member of Science Europe (Simone Fischer-Hübner)

- Member of the Advisory Board of the SPECIAL EU H2020 project (Simone Fischer-Hübner)

- Member of the Advisory Board of the Norwegian Network for PhD students COINS (Simone Fischer-Hübner)

- Steering Committee member of the NordSec conferences (Simone Fischer-Hübner)

- Member of the PET board for the Privacy Enhancing Technology Symposia (Simone Fischer-Hübner)

- Vice Chair of the Board of IEEE Sweden, Section Computer/Software Engineering Chapter (Simone Fischer-Hübner)

- Swedish Representative for IFIP (International Federation for Information Processing) Technical Committee 11 (Information Security & Privacy) (Simone Fischer-Hübner)

- Member of MSB:s Informationssäkerhetsråd (Swedish Civil Contingency Agency) (Simone Fischer-Hübner)

- Steering Committee member of Swedish National Computer Networking Workshop (Anna Brunström)

- Adjunct Board member of Compare IT-cluster (Anna Brunström)

- Chair of the IETF RTP Media Congestion Avoidance Techniques (rmcat) working group (Anna Brunström)

Editor assignments

- Editorial Board Member of the International Journal of Information Security, Springer (Simone Fischer-Hübner)

- IEEE Access (Javid Taheri)

- IEEE Journal on Selected Areas in Communications (Javid Taheri)

- Internet of Things: Engineering Cyber Physical Human Systems, Elsevier (Javid Taheri)

- Scalable Computing and Communications (SCAC), Springer (Javid Taheri)

- IEEE Transactions on Sustainable Computing (Javid Taheri)

- Computing, Springer (Javid Taheri)

Impact

For us as a university, public outreach is of vital importance. We produce and share research results through collaboration with local as well as global partners from industry, academia and the public sector. We also let others benefit from our research findings by using open source software and tools which anyone can use and modify for different purposes. By taking part in standardisation and participating in important research and development networks, we also contribute to the global development.

Student provided valuable insights on network performance

Our internationally competitive research environment helps to enhance the quality of our undergraduate education. We offer our students many opportunities to get in touch with our close partners within the industry. During the spring semester towards a Master's degree in Computer Science Gustaf Söderlund made his degree-project in cooperation with Värmlandstrafik AB. Gustaf used a mobile broadband measurement platform (MONROE) to investigate the coverage of different mobile operators (Telia, Telenor, and 3) along the regional bus routes in Värmland.

The research provided valuable insights regarding the state of network performance of the operators over the geographical region. A key conclusion was that no single operator provided the best performance at every location, but a combination of operators may be necessary to fulfill the service requirements of Värmlandstrafik regarding internet connectivity.

Alumni collaboration

Peter Dely successfully completed his doctoral studies under the supervision of professor Andreas Kassler and professor Anna Brunström at Karlstad University in 2012. Peter is now working as a patent examiner at the European Patent Office (EPO) in Den Haag, Netherlands in the field of routing and flow control. The EPO is Europe's second largest intergovernmental organisation and issues European Patents which offer a patent protection in up to 40 European countries. Peter still has regular contact with members at the department and recently gave a guest lecture on patenting computer implemented inventions.

"My doctoral studies at Karlstad University were a great experience. My supervisors and colleagues from the Computer Science department supported me in many ways to develop my own research interests and to conduct cutting-edge research. In my today's work as patent examiner, I need to quickly understand technical concepts from a wide range of fields. The doctoral courses and colloquia, the in-depth research and the regular interaction with colleagues provided me just with the knowledge and set of skills that I need for my job."

Less latency with smarter WiFi

Toke Høiland-Jørgensen, has developed a solution for smarter WiFi that is included in the latest version of Linux, the most commonly used operating system for computers, phones, TVs, etc. During his doctoral studies, Toke evaluated different algorithms and implemented them on WiFi networks where many devices (including WiFi routers for home use) use the Linux operating system.

"WiFi technology is used everywhere because it is cheap and simple. The quality is not always great, but performance can be improved by properly managing the different data flows. When there is a queue, traffic needs to be scheduled in a smart way, and this is exactly what the new algorithm does."

Contribution to standardisation

An important mechanism to bring our knowledge and research results into use by a larger technical community for the benefit of industry and society is contributions to standardisation. In relation to our research in computer networking the Internet Engineering Task Force (IETF) is an important standards organization. IETF develops and promotes Internet standards, in particular the standards that comprise the Internet protocol suite (TCP/IP), standards that are used for all communication over the Internet. Anna Brunström, professor in the DISCO profile, is the co-chair for one of the IETF working groups, the RTP Media Congestion Avoidance Techniques (rmcat) working group that develops congestion control algorithms for interactive real time media.

There is currently no generally accepted congestion control mechanism for this kind of data flows and as the amount of such traffic over the Internet increases, defining standards in this area is important. As co-chair, Anna is responsible for coordinating the work and making sure that the group progresses on its planned standards documents. During 2018, the working group has completed its first set of documents that specifies a number of experimental algorithms. It is now moving forward to gain practical experience with the algorithms and evaluate their performance over the Internet.

Conveying more knowledge to industry and the public sector

Another important way of disseminating our research is by participating in seminars aimed at industry and the public sector. We collaborate closely with Compare, a cluster comprising around 100 companies, organisations and individuals that want to develop Värmland into an attractive digital region. During the autumn, for example, Stefan Alfredsson participated in an open lunch seminar where he said more on the development of mobile broadband, the implications of 5G and the research done on 5G at Karlstad University.

Another example of research dissemination was through the research vernissage arranged by the Academy for Smart Specialisation. The DigitalWell Research project was presented, as well as a work of art that creatively combined and represented projects in the area of digitalisation of welfare services done at Computer Science, Gender studies, the Grants and Innovation Office, Mathematics, Nursing, and the Service Research Center.

In the news during 2018

Photo from the project groups' second meeting in Haifa, Israel. Tobias Pulls and Simone Fischer-Hübner, number five and six from the left.

Researchers contribute to using cloud services more securely

A European innovation project PAPAYA (Platform for Privacy Preserving Data Analytics), involving researchers from Karlstad University, will create a new platform for enhancing privacy in data analysis. The aim is to increase the security of businesses and safeguard individuals' privacy when using cloud services for data analysis.

## Major investment in the development of digital welfare services

DigitalWell Arena, a Värmland-based project that includes Computer Science at Karlstad University, was one of the winners of Vinnova's Vinnväxt competition. Over 10 years, SEK 148 million will be invested in the development of digital welfare services. The aim is to make it easy for all residents to prevent illness and receive the necessary support regarding health issues.

Michel Gokan, PhD student in Computer Science presents his research during a poster presentation.

Computer Science rated highly by experts

On 27–28 September, Computer Science at Karlstad University organised a workshop to gain external input on the research group. It was clear that the group had been developing significantly on many fronts since it was designated an excellent research environment in 2014.
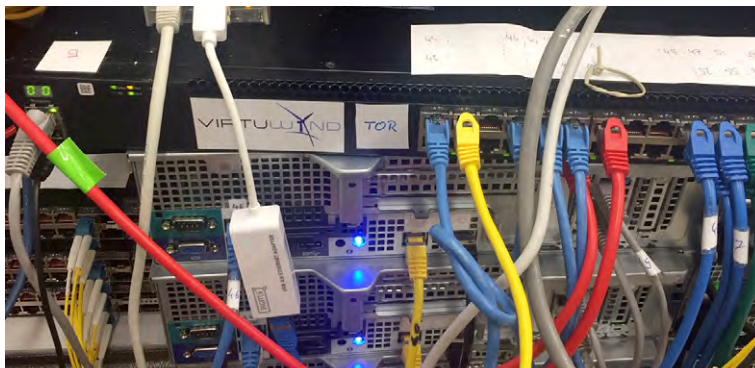
Researchers at Karlstad University develop programmable networks for wind farms

Just like many other industries, the wind power industry needs to manage large amount of real-time data. The data is transferred over a wide range of networks and affected by different kind of network components. Computer Science at Karlstad University participates in the European H2020 VirtuWind project, which develops network management systems based on virtualized network components that support wind power industry.

New project to define Internet access

Computer Science at Karlstad University is part of a new project where the Internet Foundation (IIS) and Netnod are gathering operators, technicians and other stakeholders in order to take a common approach in defining Internet access. The purpose is to make it easier for users and service providers to be aware and agree upon what is expected of the access one is paying for.

Project leader Christian Pedersen together with his project co-workers: Gustaf Söderlund, Fredrik Persson and Adrian Carlsson.

Students contribute to research and a safer digital environment

Our smartphones constantly leak personal information, and few of us know how this information is used. Computer Science students at Karlstad University have contributed to the development of Kaudroid – a tool for investigating how apps use permissions to collect user data.

High quality of doctoral programme in Computer Science

The doctoral programme in Computer Science at Karlstad University is reviewed to be of high quality in an evaluation made by UKÄ, the Swedish Higher Education Authority. The evaluation stated that:

- The doctoral students' participation in research projects contributes to them gaining a broad knowledge and understanding of the subject, and to their opportunity to form contacts that can be used in their future careers.

- The doctoral students' participation in teaching contributes to the development of their ability to support the learning of others and to contribute to the development of society.

Digitalisation, medicine and health in focus

The International Symposium on Computer-Based Medical Systems, IEEE CBMS 2018, was held on 18–21 June at Karlstad University. Around 100 international researchers and other experts in the area of medical and health technology participated in the symposium to present their own research and exchange knowledge and experience with others.

Funding for two IT projects at Karlstad University

Two IT projects at Karlstad University will receive funding from the Swedish Internet Foundation. One project will focus on improving fifth generation mobile networks, 5G, and the other on further developing the anonymity service Tor.

Tobias Pulls, Associate Professor in Computer Science and responsible for the project "Improving anonymity network Tor".

Per Hurtig, Associate Professor in Computer Science and responsible for the project "More effective data transport for 5G".

COMPUTER SCIENCE
DATAVETENSKAP

"Computer Science has during 2018 continued its development journey in a very successful way and proven that the research group is a good example of a research environment that can combine research-projects and create impact on both international, national and regional level. Computer Science was during 2018 instrumental for the regional initiative Digital Well Arena that was granted national Vinnova (Vinnväxt) funding in parallel with starting up a number of European Horizon-projects and other global networks and initiatives. For Karlstad University that capability is very important since it clearly strengthen the university brand as a global recognized university with a strong national and regional anchoring."

Johan Sterte, Vice Chancellor at Karlstad University.