CWC Oulu in Brief

Prof. Jari Iinatti
Head of CWC – Networks and Systems
Key Figures of the University of Oulu

- Established in 1958
- Total funding 240 M€
- 10 faculties
- 14,000 students
- 2,900 employees
- ~220 professors
- ~1,600 researchers/teaching
- ~25 study programmes
- 18 international M.Sc. programs

Faculties
- Oulu Business School
- Oulu Mining School
- Oulu School of Architecture
- Biochemistry and Molecular Medicine
- Humanities
- Education
- Science
- Medicine
- Technology
- Information Technology and Electrical Engineering (ITEE):
  - 12 Research Units
FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING (ITEE)

CRITICAL MASS IN OUR RESEARCH FOCUS AREAS
International staff > 35%
Multi-disciplinary expertise resulting new innovations

COMPETENCE CUMULATION
Experienced professors
Each professor has a seasoned team

OFFERING STABLE ENVIRONMENT
Seasoned in winning funding
Excellent local and intl. networks

30M€ ANNUAL FUNDING
41 PROFESSORS
500 EXPERTS

STRONG PORTFOLIO OF RESEARCH PROJECTS
Well-balanced between fundamental and applied research
Long R&D tradition with local and international companies

200 PROJECTS
30 PHD
150 MSC
12 INTERNATIONALLY ACCLAIMED UNITS

HIGH-QUALITY EDUCATION
Competent workforce for companies, research institutions and public sector
Internationally reviewed and credited research units
Balanced fundamental and applied research

MULTI-DISCIPLINARY ICT RESEARCH
500 EXPERTS
41 PROFESSORS
30M€ ANNUAL FUNDING
200 PROJECTS
30 PHD
150 MSC
12 INTERNATIONALLY ACCLAIMED UNITS

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<table>
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<th>ITEE RESEARCH UNITS</th>
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| **CAS** | CIRCUITS AND SYSTEMS  
PROF. JUHA KOSTAMOVAARA |
| **MIC** | MICROELECTRONICS  
PROF. HELI JANTUNEN |
| **OPEM** | OPTO-ELECTRONICS AND MEASUREMENT TECHNIQUES  
PROF. TAPIO FABRITIUS |
| **CWC-RT** | CWC- RADIO TECHNOLOGIES  
PROF. MARKKU JUNTTI |
| **CWC-NS** | CWC - NETWORKS AND SYSTEMS  
PROF. JARI IINATTI |
| **CMVS** | CENTER FOR MACHINE VISION AND SIGNAL ANALYSIS  
PROF. OLLI SILVEN |
| **BISG** | BIOMIMETICS AND INTELLIGENT SYSTEMS  
PROF. JUHA RÖNING |
| **M3S** | EMPIRICAL SOFTWARE ENGINEERING IN SOFTWARE, SYSTEMS AND SERVICES  
PROF. MARKKU OIVO |
| **UBICOMP** | UBIQUITOUS COMPUTING  
PROF. TIMO OJALA |
| **OASIS** | OULU ADVANCED RESEARCH ON SERVICE AND INFORMATION SYSTEMS  
PROF. HARRI OINAS-KUKKONEN |
| **INTERACT** | HUMAN COMPUTER INTERACTION AND HUMAN-CENTERED DEVELOPMENT  
PROF. NETTA IIVARI |
| **ACM** | APPLIED AND COMPUTATIONAL MATHEMATICS  
PROF. KEIJO RUOTSALAINEN |
Key Figures of the University of Oulu

- Founded 1995 as a research programme to improve collaboration between academia and industry.
- Basic operation model for the first 10-years: funding only through competition.
- Was later merged to the Faculty of ITEE as two separate groups: CWC – Radio Technologies and CWC – Networks and Systems.
- Research and teaching staff: ~ 150 (6 professors).
- Very international staff – more than half non-Finns.
- Total funding ~ 9 M€ / year (75% external funding).
CWC Approach

Mission
- Research driven
- Graduates for research or business career
- New technology for real use
- Collaborate globally with companies

Objectives
- Forerunner
- Valued partner for research cooperation
- Research driven training and education
- Fast reacting
  - To the needs expressed by partners
  - Changes in the operation environment
- Interaction with the surrounding community
  - Projects realised with external funding
  - Through long-term national research partners
CWC Key Expertise Areas

- Wireless communications and networking
- Transceiver and radio frequency (RF) technologies
- Radio channels, antennas and propagation
- Optimization and algorithms
- System design, integration, verification and validation
- Wireless applications: industrial internet, medical and health, smart energy grids, security and defense
CWC Academic Output

**Dr. Sc. (Tech.) Output from Communications Engineering**

- **CWC founded**

**Authors**
Top 500 authors, by number of publications at the University of Oulu over the period 2014 to 2016. Note that some authors may no longer be affiliated with the University of Oulu.

<table>
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<td>1. Järvelin, Marjo Rilitta</td>
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<td>3. Latva-aho, Matti</td>
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<td>5. Bennis, Mehdi</td>
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CWC’s Role in Technology Transfer

- Spinn-offs:
  - Sensinode
  - KNL Networks (Kyynel)
  - Solmu

Timeline:
- 1986: Spread Spectrum Technology Research
- 1990: Tactical Data Link and SDR solutions
- 1997: Multicarrier and MIMO technology Research
- 1999: IMT-A concept from WINNER projects
- 2007: 5G Technology Research
- 2010: 5G Technology Networks
- 2015: First CR call over live network; First LTE LSA trial

3G standard technology developed in FRAMES project
Proposal for IEEE802.15.3a and related ASIC
RAT Research Agenda

- Flexible duplexing for mmWaves
- Polar vs. LDPC codes at mmWaves
- Hybrid beamforming for mmWaves
- Secure low latency machine type communication protocols
- Positioning in beamformed 5G radios
- V2X for highspeed mobile systems at mmWaves
- RAN architecture design and optimization at mmWaves driven by micro-operator functions
- Secondary radio access utilizing radar bands
- 5G radio access at 10GHz frequency bands: from channel models to MIMO transceiver design
- Beamformed backhauling at 28GHz
CSP Research Agenda

• **Wireless System Algorithms**
  - Radio resource management and transceiver algorithms and their impact on system performance

• **Transceiver Algorithms, Computation Platforms and Design Tools**
  - Algorithm and architecture/implementation co-design

• **Crosslayer Statistical Inference**
  - End-to-end optimization with joint source-channel coding or compressed sensing
  - Mostly for WSNs

• **Nanoscale Communication and Algorithms**
  - Nanoscale communication devices, protocols and networks, e.g., for in-body communications
• **Antennas and propagation**
  - Long-term experience from antenna implementations to propagation measurements
  - MIMO over-the-air (OTA) test bed for mobile devices towards CTIA standardization
  - Broadband antennas for infrastructure and wearable medical applications
  - 5G Channel Measurements

• **RF Transceiver architectures and implementation**
  - New, strong research strategy towards 5G
  - RF Implementation Challenges for 5G
Wireless Networking

- **Network architectures**
- **Multioperator Spectra Management, sharing / Spectra trading**
- **Software Defined Networking (SDN)**
  - Decouple the control and data planes
  - Enable external control through a logical centralized software entity called the network controller
  - Network Functions runs as software application at the application plane
- **Network Functions Virtualization (NFV)**
  - Network functions are implemented independent of the physical resources and are deployed in virtualized environments, such as mobile clouds
  - Virtualize a set of network functions by deploying them as software packages in a cloud environment
  - Services are available on a demand basis
- **Mobile Edge Computing (MEC)**
  - MEC is a key enabler for IoT and mission-critical vertical solutions.
  - MEC is one of the key technologies for enabling the transformation to 5G architecture, helping to satisfy the demanding requirements for the 5G era in terms of expected throughput, latency, scalability and automation
Wireless Systems

– Addresses various application areas of wireless communication
  • Utilize and integrate the results from other research groups, which focus on fundamental research
  • In particular, we seek new partners and industries

– The main theme is supporting the renewal of local ICT ecosystem
  • Contacting and networking with companies within and outside the telecommunications sector
  • Preparing research projects, particularly with new industrial partners
  • Maintaining links with the public sector, city of Oulu in particular

– Main projects
  • CORNET: Dynamic spectrum sharing for Public Safety
  • 6Aika: Open innovation platforms
  • P2P Smartest: Smart energy grids, BC-DC: Cloud Computing as Enabler for SE
  • 5GTN+: 5G trials for Vertical Businesses on top of 5G test network

– Key topics in the future; in addition to the ICT ecosystem renewal
  • Business models for city networks
  • City networks as platforms for Smart Cities / IoT
  • City networks as integral parts of 5G networks
Wireless Medical Communications: WiMeC

Topics (done, started, in list):
- Dual use in homes and institutions
- Assumptions and channel models for WBAN
- Performance evaluation of ultra wideband receivers
- Low-power MAC protocols for low data rate WBANs
- Dependable WSN networks
- Robustness, security and secrecy
- Antennas: including on-body and implanted
- Body tissues and radio frequency
- Thermal effects and safety margin
- Environmental challenges in medical WBANs
- On-body and in-body communications
- Location tracking
- Contribution to ETSI TC SmartBAN PHY & MAC Standards
- Nanoscale communications
- Mobile clouds for medical ICT
- Visible light communication for medical ICT

WBAN is the key element