



CWC Oulu in Brief

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Head of CWC – Radio Technologies



Key Figures of Centre for Wireless Communications (CWC)

- 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 research units:
 - CWC – Radio Technologies
 - CWC – Networks and Systems.
- Research and teaching staff: ~ 180 (10 professors).
- Very international staff – more than half non-Finns.
- Total funding ~ 10 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

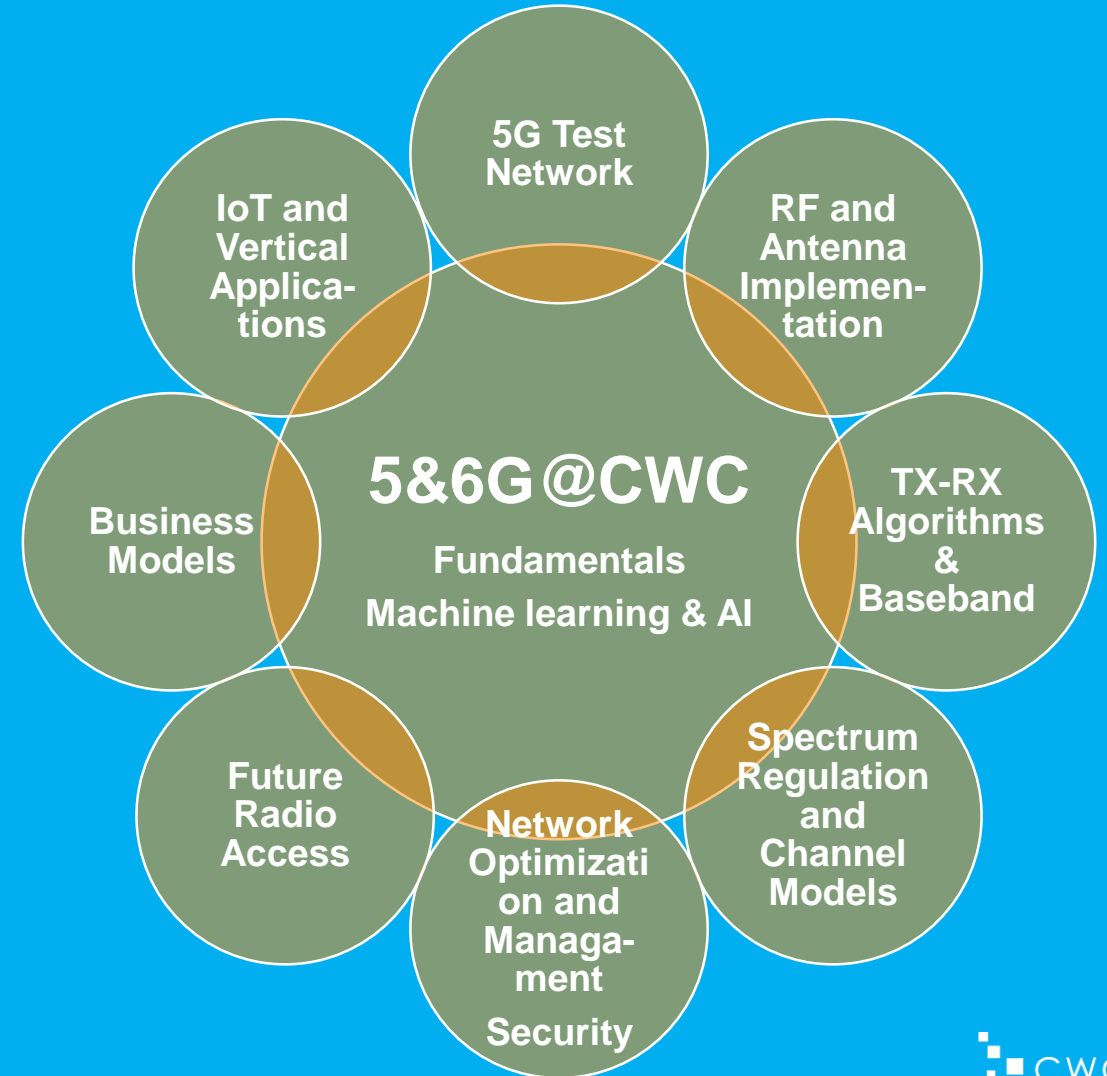
Objectives

- 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

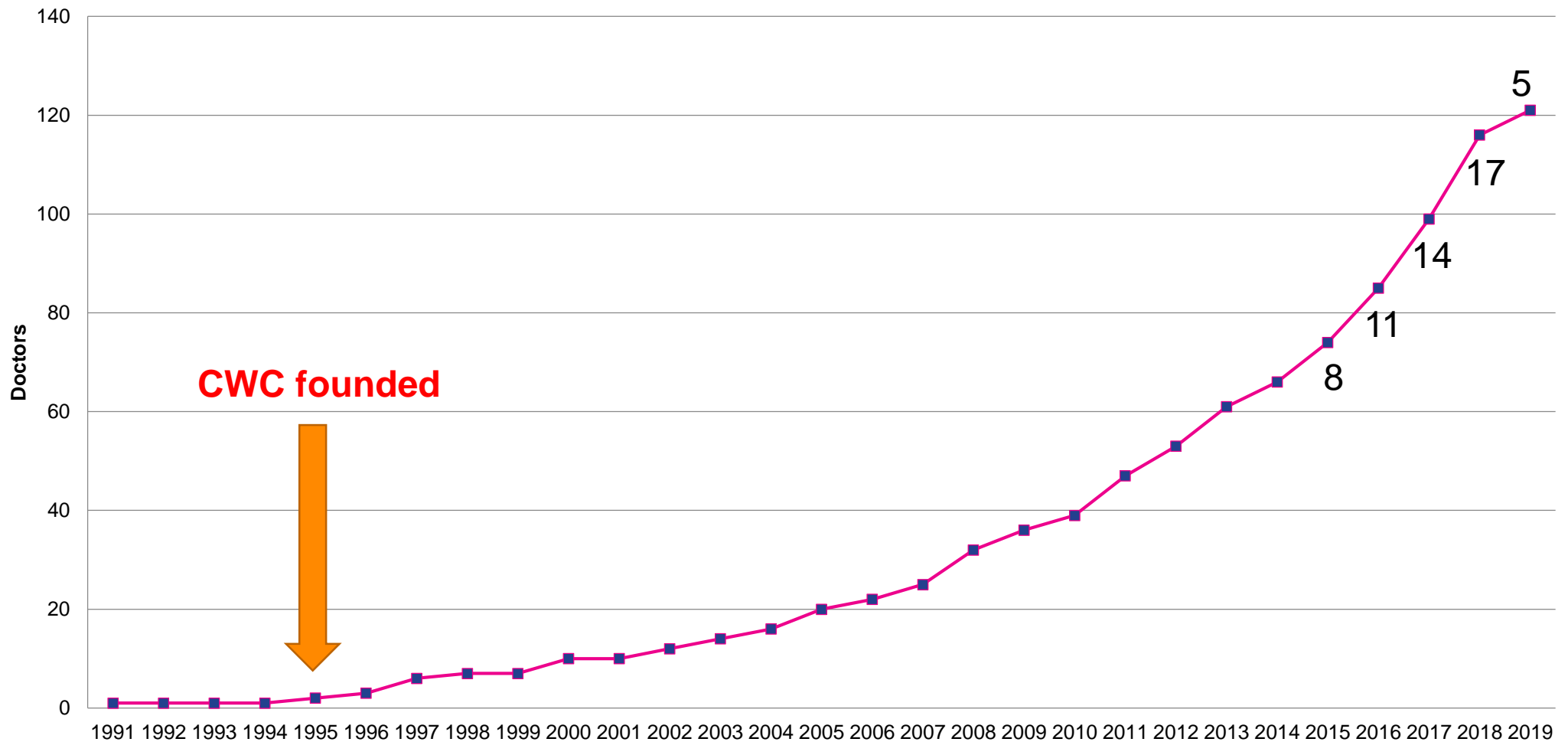
- Wireless communications and networking
- Transceiver and radio frequency (RF) technologies
- Radio channels, antennas and propagation
- Optimization, ML, AI and algorithms
- System design, integration, verification and validation
- Wireless applications: industrial internet, medical and health, smart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





CWC Academic Output

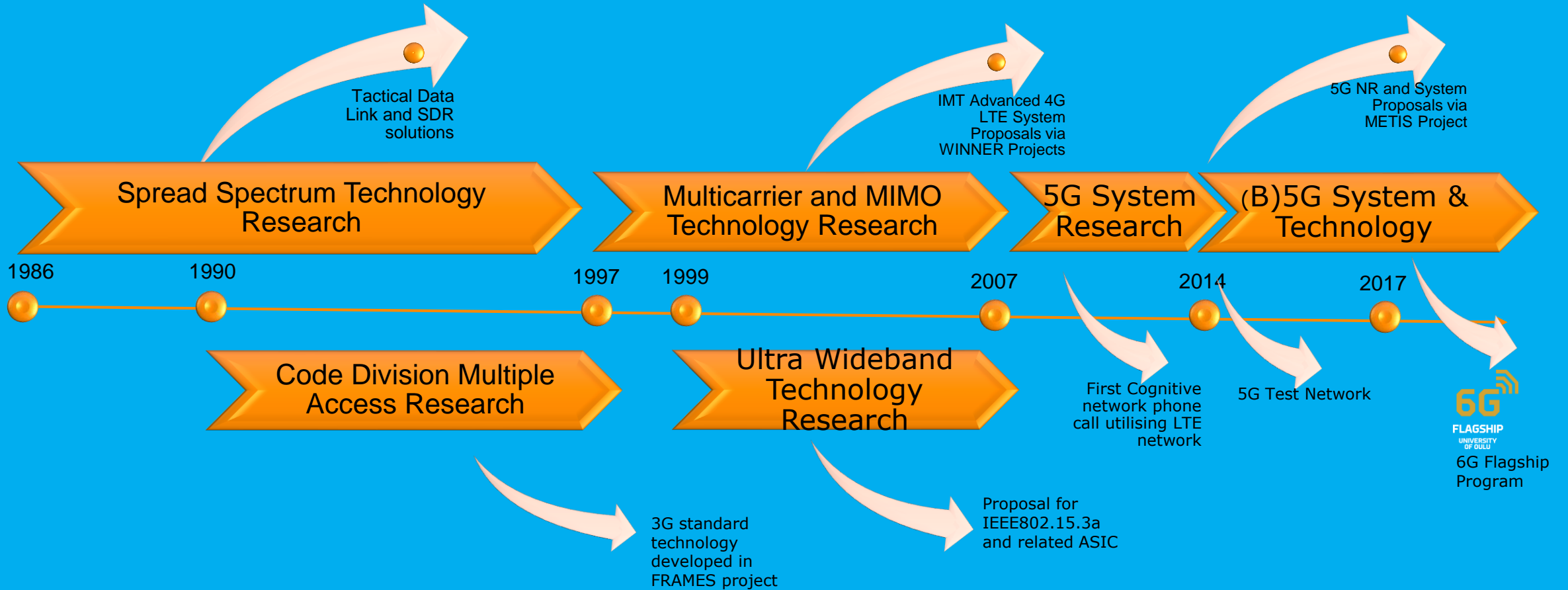
Dr. Sc. (Tech.) Output from Communications Engineering





CWC's Role in Technology Transfer

- + Spin-offs:
 - Sensinode
 - KNL Networks (Kyynel)
 - Solmu





CWC's Research Groups



Radio Access Techniques (RAT)

Matti Latva-aho, N. Rajatheva, Hirley Alves



Wireless Systems (WS)

Ari Pouttu, Marcos Katz, Jussi Haapola



Intelligent Connectivity & Networks (ICON)

Mehdi Bennis



Critical Communications Systems (CCS)

Harri Posti, Harri Saarnisaari



Communications Signal Processing (CSP)

Markku Juntti, Antti Tölli, Janne Lehtomäki



Networking (NET)

Mika Ylianttila, Tarik Taleb



RF Engineering (RFE)

Aarno Pärssinen, Markus Berg, Marko Leinonen



Wireless Medical Communications (WiMeC)

Jari Linatti, Matti Hämäläinen

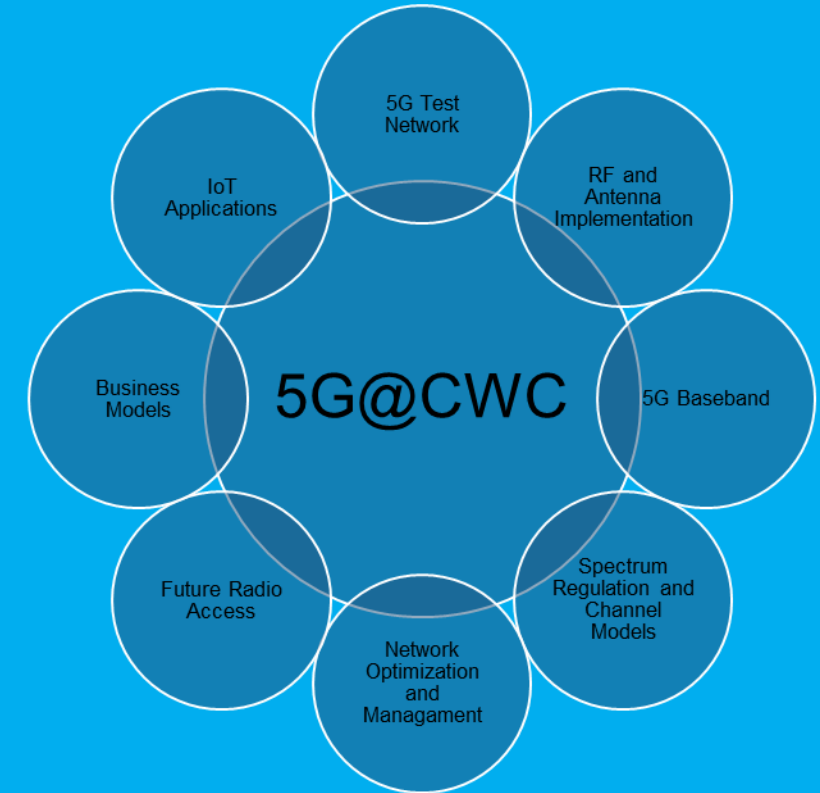
CWC-RT

CWC-NS



RAT Research Agenda

- L1 – L3 for future mobile radio systems
- **5G flavored topics:**
 - Flexible duplexing for mmWaves
 - Polar vs. LDPC codes at mmWaves
 - Hybrid beamforming for mmWaves
 - 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
 - Beamformed backhauling at 28GHz
- **6G research:**
 - URLLC optimization for different verticals: from theory to algorithms
 - AI and ML for beam acquisition at mmWaves
 - Sub-THz and THz communications

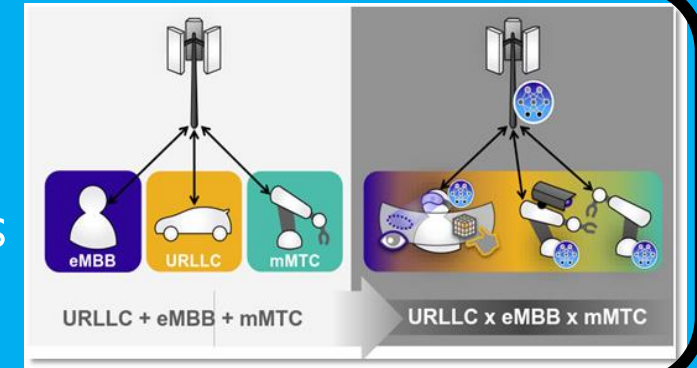




ICON Research Agenda

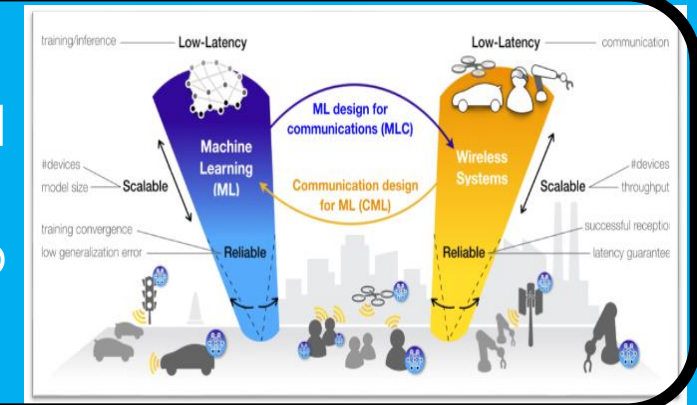
URLLC2.0: Ultra-reliable and low-latency communication and control

- System design based on rare/extreme events characterization
- ML-empowered channel/blockage prediction
- Low-latency and reliable control over wireless (federated/collaborative/autonomous control)



Edge AI: Distributed wireless AI/ML @ the Edge

- Theoretical and algorithmic principles of communication and energy-efficient ML with applications to verticals
- Low-latency, reliable and scalable ML over wireless subject to resource constraints & wireless links.
- Focus on ML4Com + Com4ML



Ongoing Projects

- CARMA/SMARTER/MISSION/CONNECT (AKA)
- SAFARI/NOOR (UO)
- AIMS & ELLIS (gifts)



CSP Research Agenda

- **Research approaches**

- Fundamental methodology and theoretical foundations via information and comms. theory
- Optimization, machine learning (ML) and artificial intelligence (AI) for transceivers and systems
- Algorithm and architecture co-design and implementations
- Baseband (BB) and radio frequency (RF) processing interplay and joint design

- **Current beyond 5G and 6G research topics**

- Radio resource management and transceiver algorithms
- System performance and channel models via ray tracing
- Hybrid RF / baseband (BB) beamforming / precoding for mmWave and (sub-)THz systems
- ML and AI for transceiver and system optimization and algorithm design
- Detection, channel estimation and decoding for 6G and use of AI in transceivers
- Positioning and localization
- End-to-end optimization with joint source-channel coding or compressed sensing
- Age of information in networks



RF Systems

TRx architectures & implementation

Antennas & propagation

- **Antennas and propagation**
 - Long-term experience from antenna implementations to propagation measurements
 - MIMO over-the-air (OTA) test beds for mobile devices and mmW phased arrays
 - Broadband antennas for infrastructure and wearable medical applications
 - 5G/6G Channel Measurements
- **RF Transceiver architectures and implementation**
 - From system concepts to RF architectures and IC solutions
 - New, strong research strategy towards 6G
 - RF Implementation Challenges for 5G and 6G
 - RF lab up to 300GHz range under construction



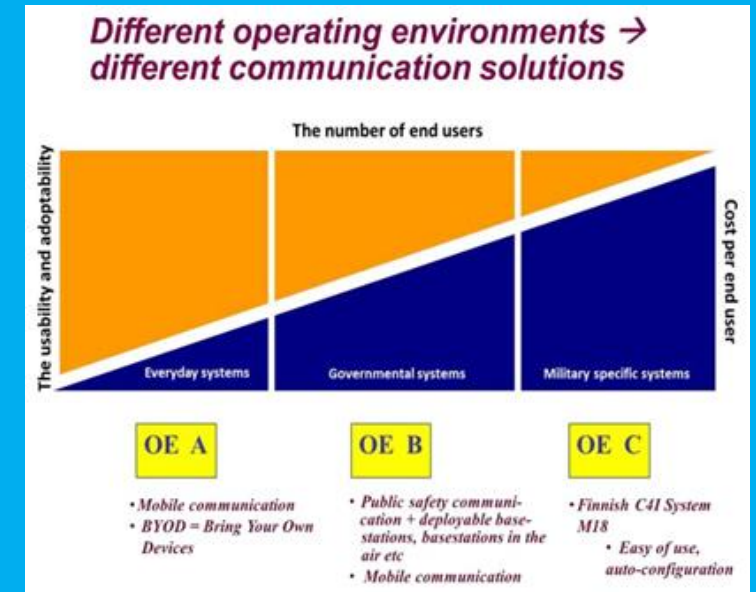
Wireless Systems

- **Addresses various application areas of wireless communications**
 - 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**
 - 5G-FORCE: 5G trials for Vertical Businesses on top of 5G test network
 - 5GVIIMA: 5G Network for industrial environments
 - 5GDrones: Unmanned Aerial Vehicle Vertical Applications' Trials Leveraging Advanced 5G Facilities
 - SAT5G: Satellite and Terrestrial Network for 5G
 - BC-DC: Cloud Computing as Enabler of large scale variable distributed energy solutions
 - APPSTACLE
- **5GTest Network**



Critical Communications Systems

- **Mission:** The scope of the group is Critical Communication. It researches wireless technologies for operating environments OE B and OE C (critical and military communications).
- **Vision:**
 - Hybrid commercial-dedicated solutions based on LTE, 5G and beyond 5G are widely used in **OE B**.
 - State-of-the-art wireless research is applied for tactical communications and electronic warfare systems in **OE C**.
- **Main projects**
 - PVTO2017: Everyday technologies for critical communications
 - MAENA: Waverforms for military communications
- **Key topics in the future**
 - Hybrid networks for authorities' needs: security, availability, reliability, cost efficiency.
 - Communication waveforms and architectures for military applications.





Wireless Networking

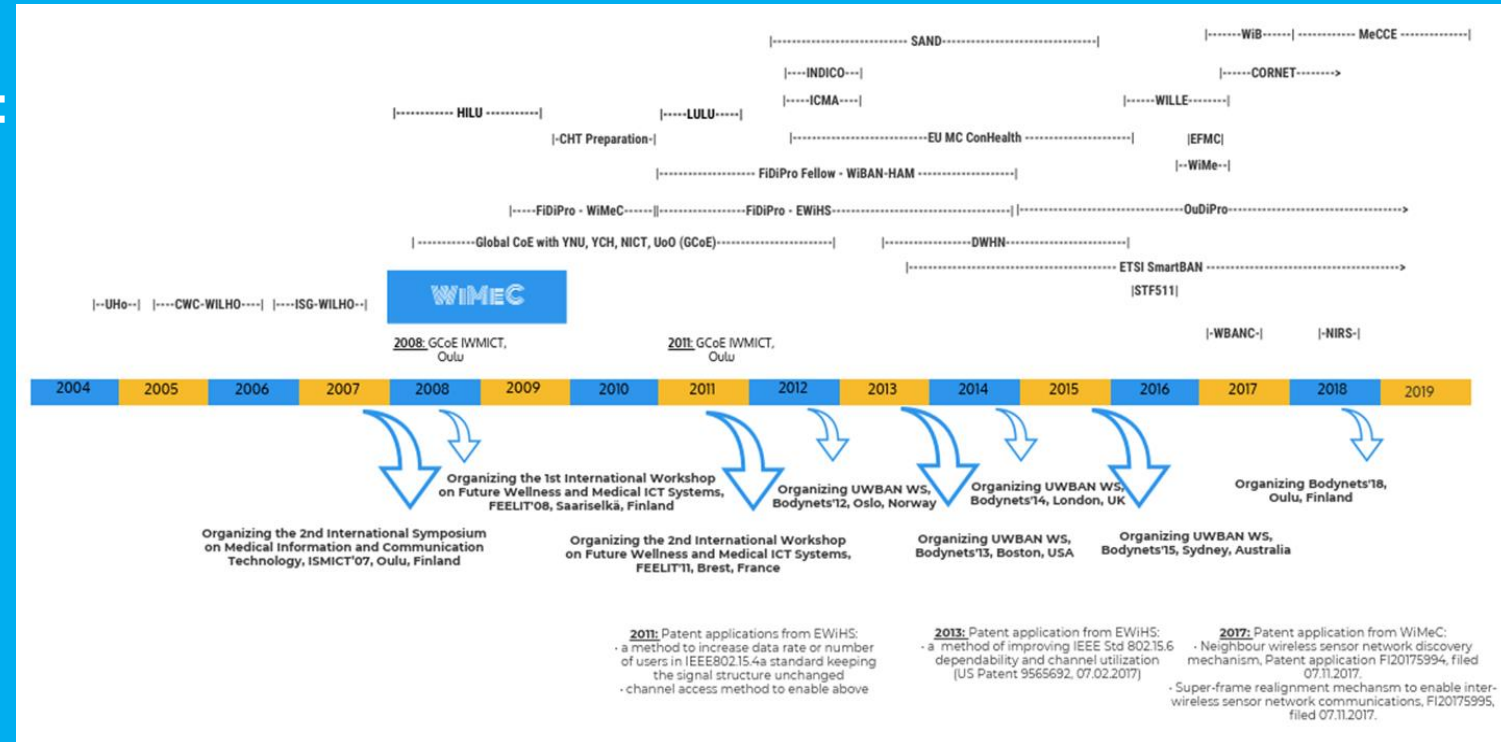
- **Network architectures**
- **Multioperator Spectra Management, sharing / Spectra trading**
- **Software Defined Networking (SDN)**
 - Decouple the control and data planes
 - Enable external control through a logical centralized software entity called the network controller
 - Network Functions runs 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 Medical Communications: WiMeC

Topics (done, started, to do):

- 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
- On-body and implanted antennas
- Body tissues and radio frequency
- Thermal effects and safety margin
- Environmental challenges in 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 MICT



Medical ICT related research at CWC has so far the following outputs:

- Books and chapters: 3
- Journal articles: 28
- Conference papers: 107
- Patent applications: 5
- M.Sc. theses: 7
- Dr. Thesis: 5

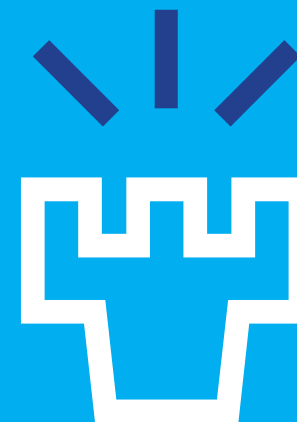
WBAN is the key element



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