5G and SDR Research at TU/e

SDR Evening at Fontys
28 May 2019

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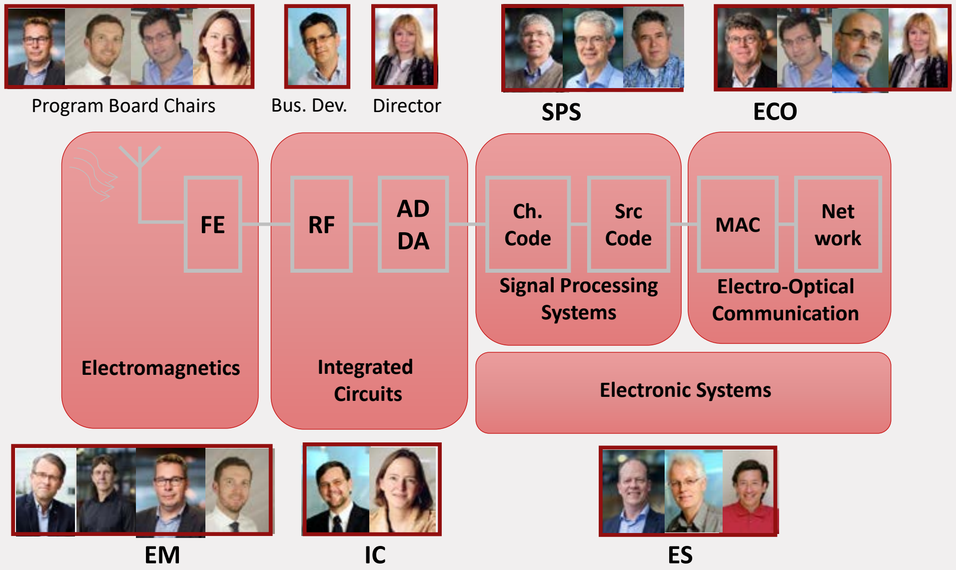
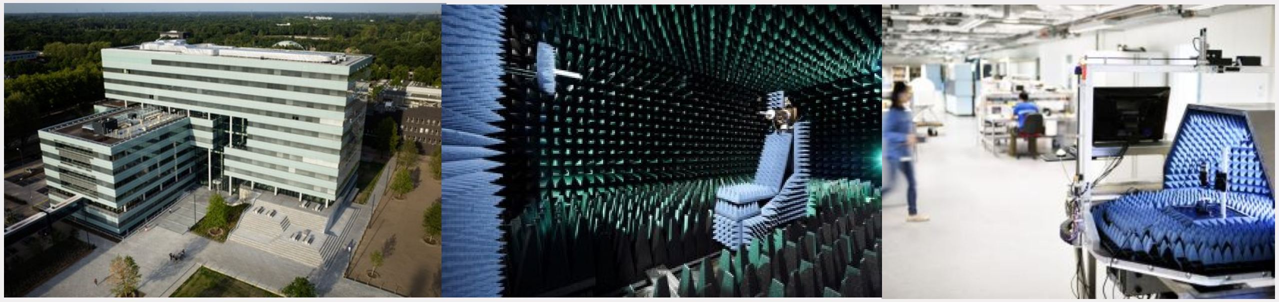
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Center for Wireless Technology Eindhoven (CWTe)

Center for Wireless Technology (CWTe)

- Founded in 2007
- Cooperation between 5 groups of the 9 groups in Electrical Engineering
- Multidisciplinary applied research questions
- +/- 50 PhD on wireless topics
- 3 M€ per year on research funding
- CWTe labs



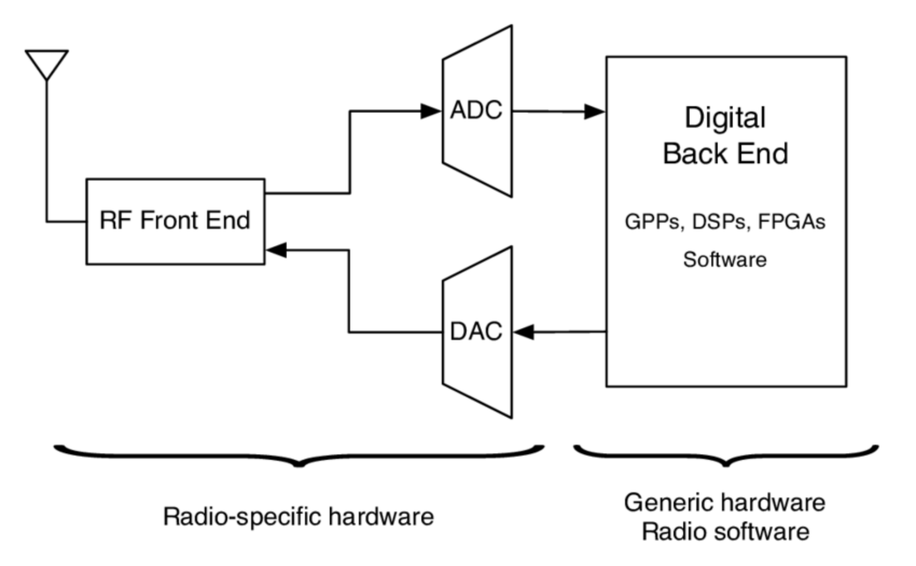


SDR in 5G

Software Defined Radios

Flexible front-ends

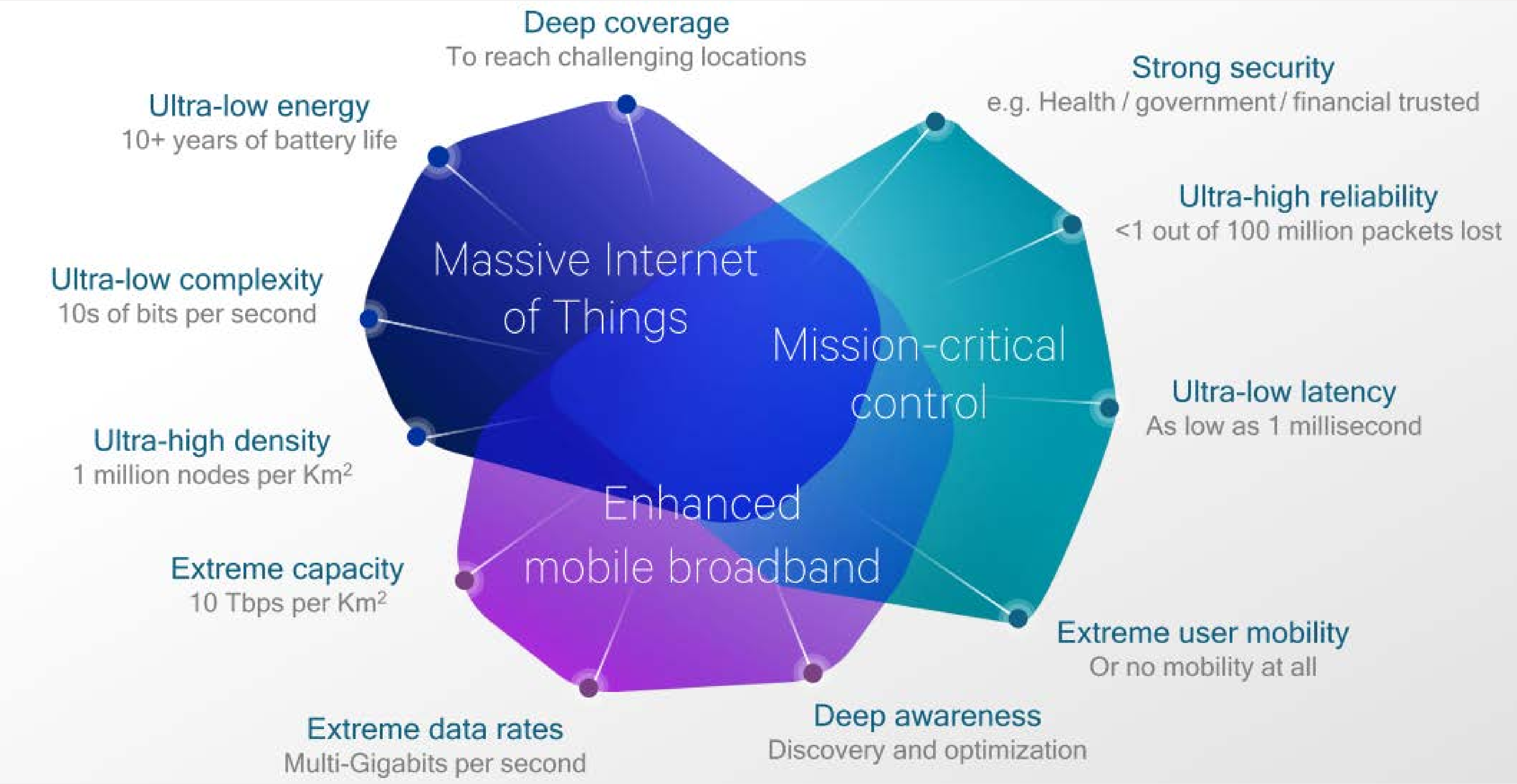
High-performance digital hardware



The case for SDR

- Agility as key requirement for system design
- Large number of frequency bands that need to be supported 40 in LTE and many more with 5G! (licensed and unlicensed)
- Many protocols in the same band (WiFi, BT, etc.)
- Digital domain processing can improve the overall quality of the transmitted signal
- Beamforming and multiple-input multiple-output (MIMO) systems
- Cognitive radio
- Standard upgrade
- Growing choice of development boards
- Open source tools and libraries (e.g.,GNU Radio)

5G Objectives*



**From Qualcomm Technologies, Inc. February 2016*

5G NR spectrum types and bands

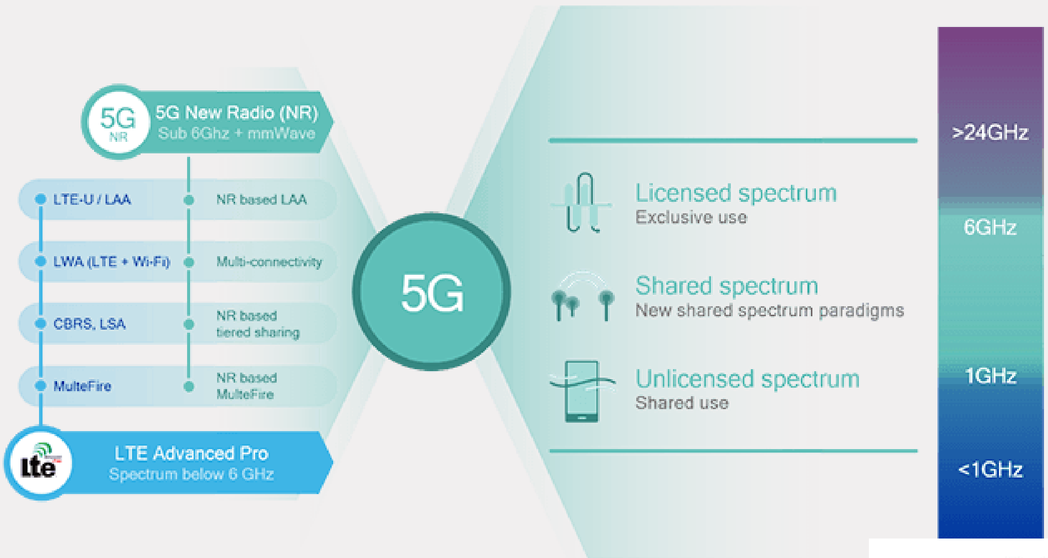


Image: Qualcomm

Image: www.sharetechnote.com

Key wireless technologies of 5G NR (1)

Scalable OFDM numerology

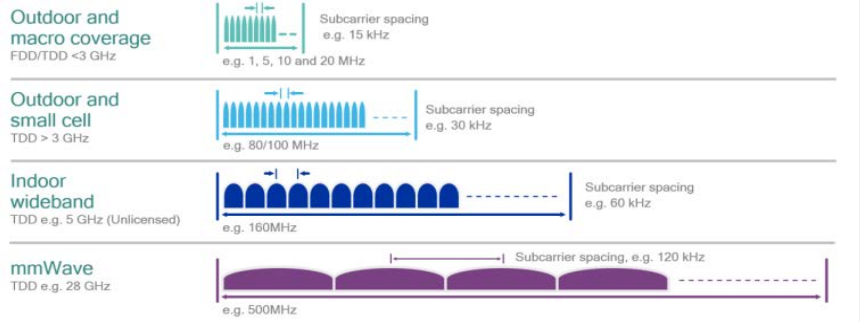
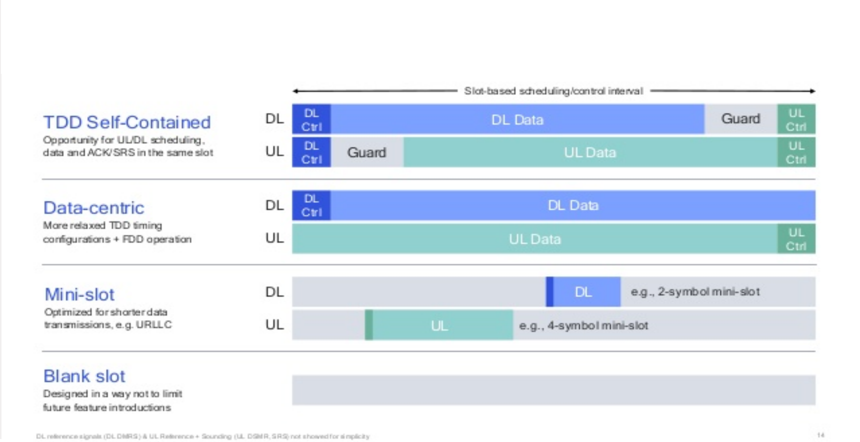
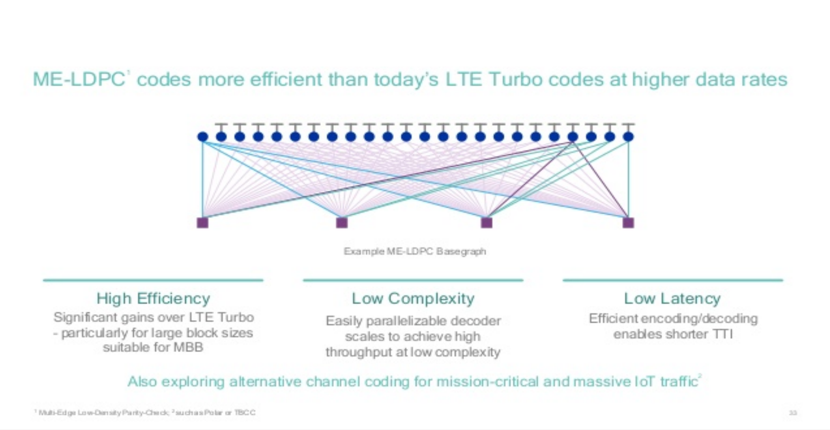


Image Qualcomm

Flexible slot structures



Advanced channel coding



Images: Qualcomm

Key wireless technologies of 5G NR (2)

Massive MIMO

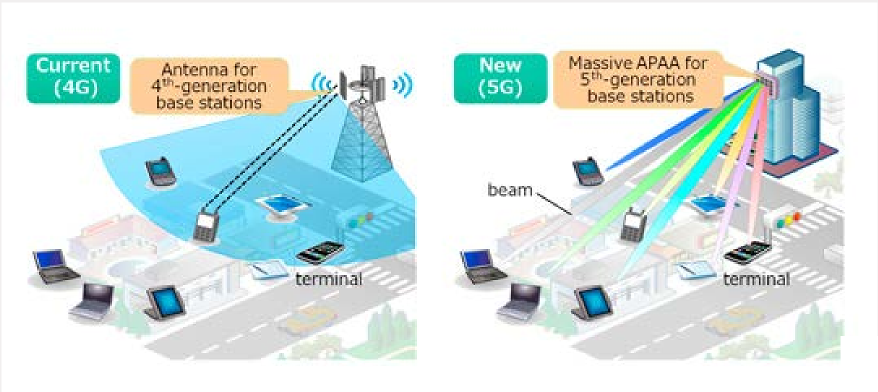


Image: www.mwrf.com

Mobile mmWave

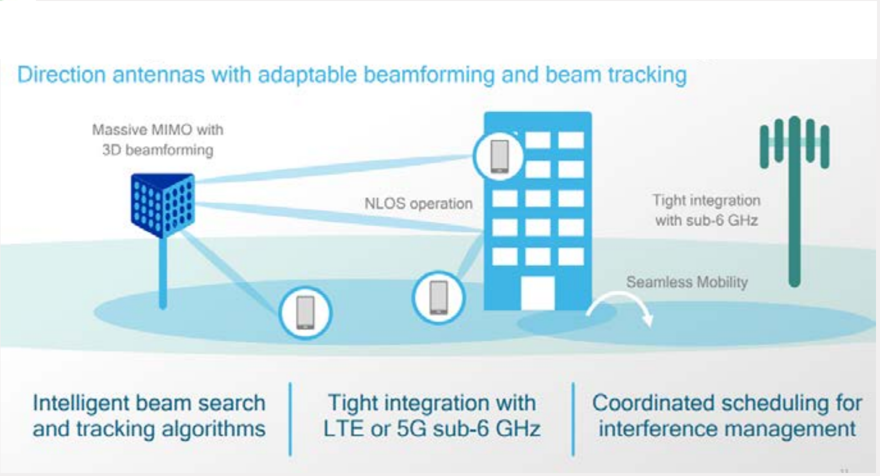


Image Qualcomm

Extending the SDR concept in 5G

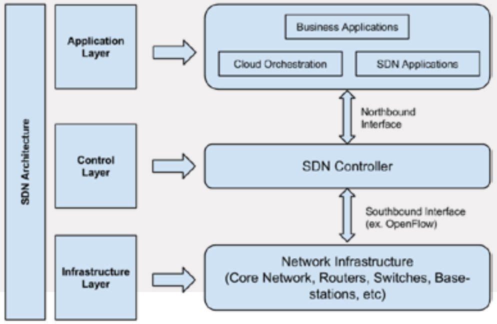
- Flexibility of SDR necessary due to the high complexity of system, diversity of standards and spectral bands, access mechanisms, etc.
- More software in the network: Software-defined 5G Systems

Cloud-RAN (C-RAN)

- SW implementation of network functions on top of general-purpose processors
- Network functions on top of virtualized (and shared) computing, storage, and network resources

Software Defined Networking

- Separation of data and control planes
- Equipment can be configured externally through vendor-independent management software



Images from https://www.openairinterface.org

Network slicing

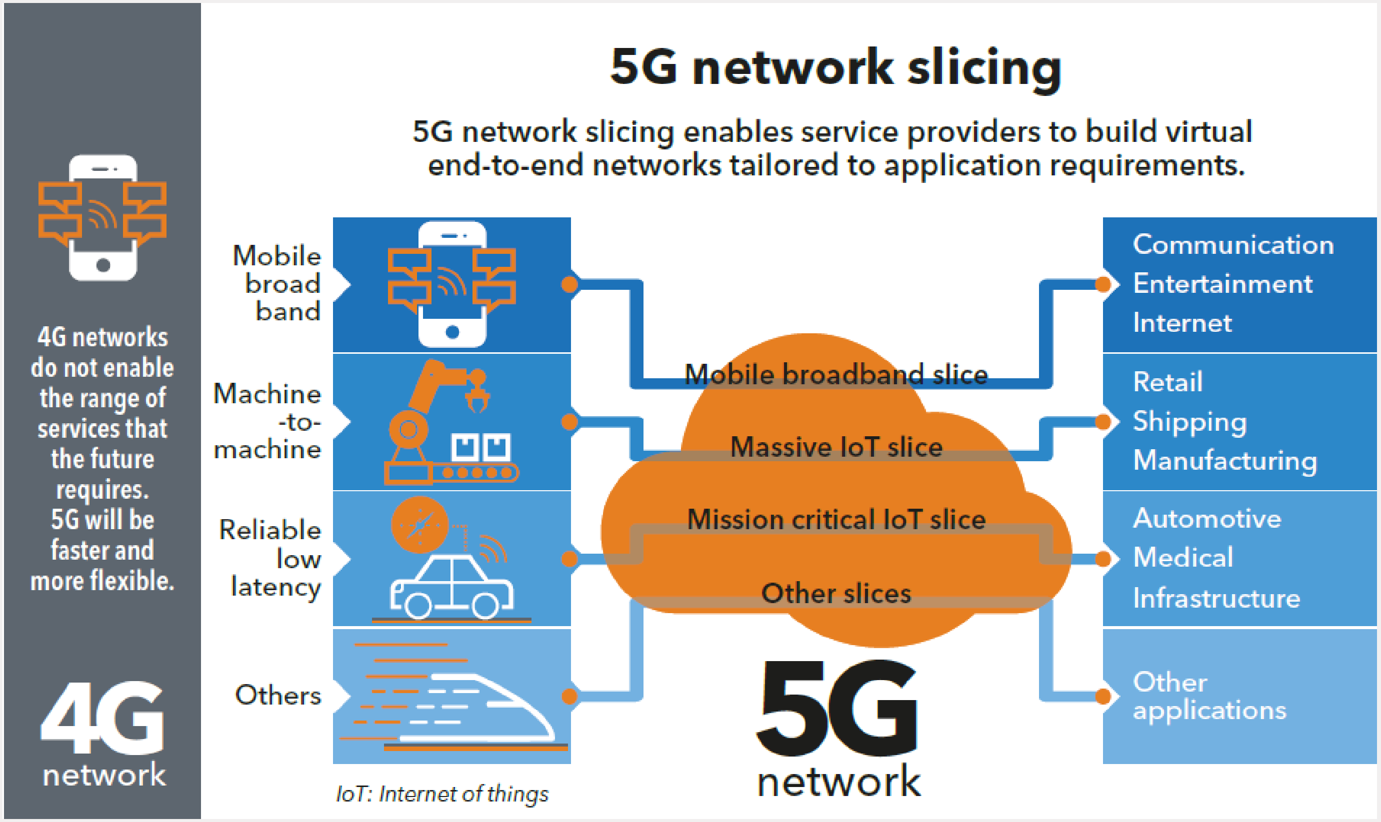


Image: ITUNews

SDR Projects

SDR projects at CWTe

- SDR as a tool to support research an education
  - Commercial SRD (NI USRP 2900s/2920s, AD ADALM PLUTO)
- SDR architecture and components
- Examples of SDR projects:
  - LINC transmitters using Dual-polarized Power-Combining Antennas
  - Wireless plasticity in dense IoT networks
  - Constellation shaping
  - Radar-based communications
  - Par4CR: Architecture for SDR and CR
  - SDR in teaching

LINC transmitters using Dual-polarized Power-Combining Antennas

- Linear amplification with nonlinear components (LINC) concept

$$S(t) = E(t)\cos[\omega t + \theta(t)]$$

amplitude and phase variations

$$S_2(t) = \frac{E_m}{2}\{\cos[\omega t + \theta(t) - \phi(t)]\}$$

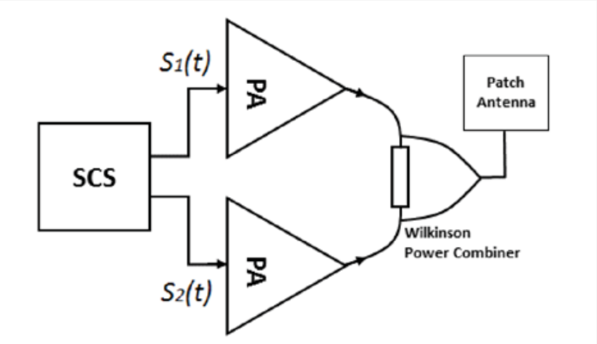
$$S_1(t) = \frac{E_m}{2}\{\cos[\omega t + \theta(t) + \phi(t)]\}$$

where $E_m = \max|E(t)|$

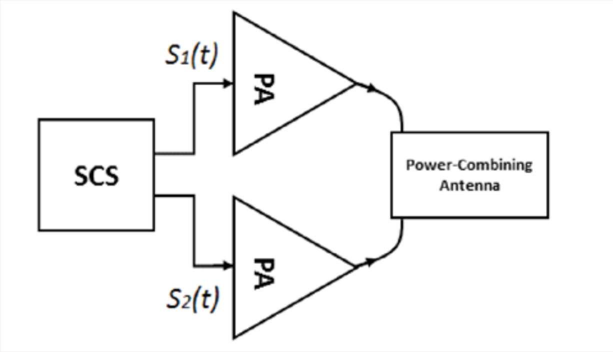
$$\phi(t) = cos^{-1}\frac{E(t)}{E_m}.$$

constant envelope only phase variations

- High-efficiency non-linear amplifiers can be used



Conventional LINC



LINC power-combining antenna[1]

[1]Tresnawan, D., P. F. M. Smulders, B. van Ark, and A. B. Smolders. "Linear LINC transmitters using dual-polarized power-combining antennas." 12th European Conference on Antennas and Propagation (EuCAP 2018) (2018): 805-4

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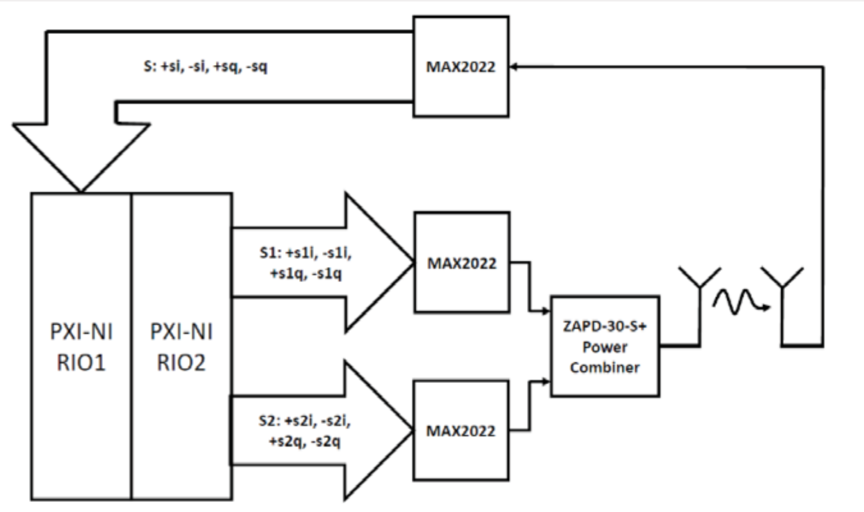
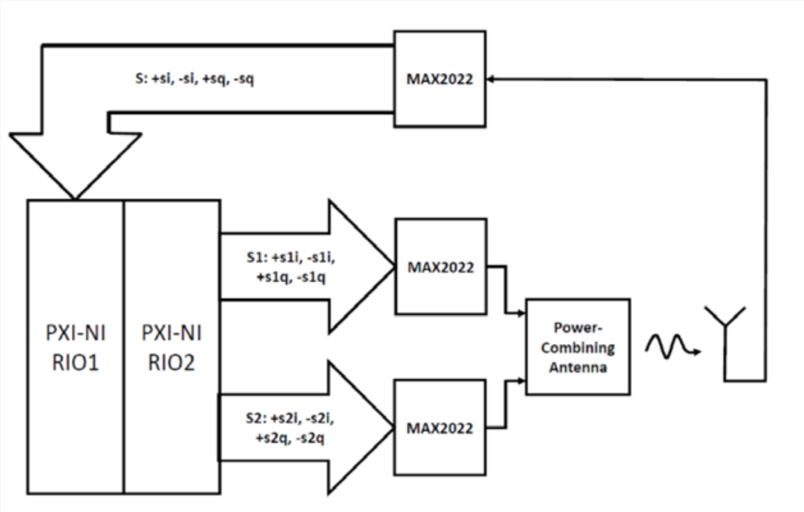
LINC transmitters using Dual-polarized Power-Combining Antennas

Measurement set up with SDR:

- NI PXI with two FlexRIO FPGAs
- Controlled by LabVIEW

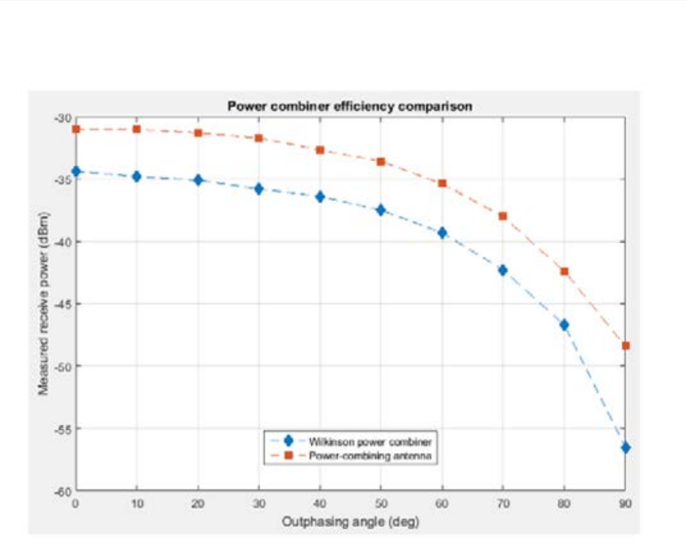


Set up with conventional LINC



Set up with power-combining antenna

LINC transmitters using Dual-polarized Power-Combining Antennas



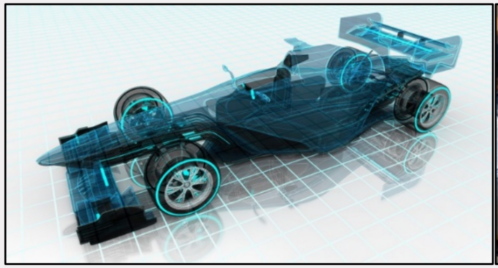
Measurement set up

	EVM
Wilkinson power combiner	0.214%
Power-combining antenna	0.244%

3dB more efficient than conventional

Wireless neural plasticity: problem

250-300 sensors



6000 sensors

25000 sensors

Enough power

⇩

Keep data locally
Keep processing locally
Bring intelligence locally

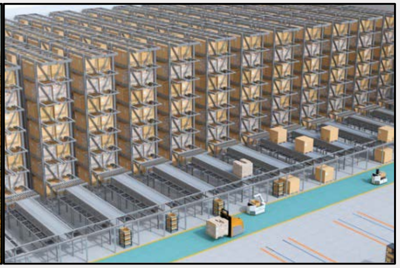
⇩

edge/fog computing

tight profit margins

remote-inaccessible

disposable-inaccessible



Low power

⇩

Keep data locally
Processing in-network
Bring intelligence in-network

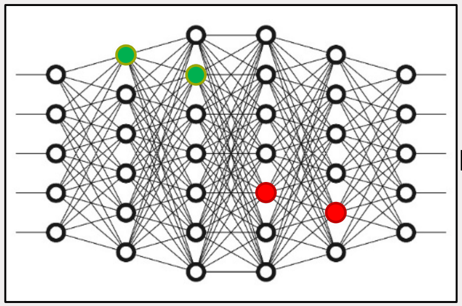
⇩

in-built ANNs

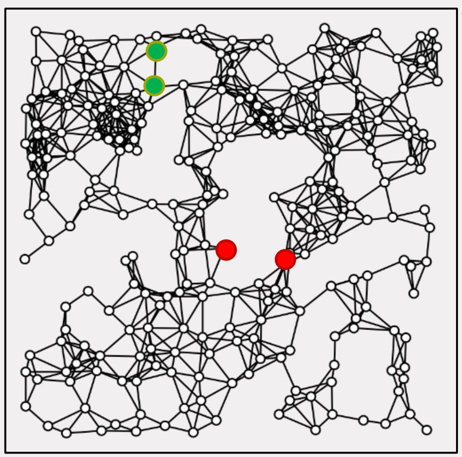
Wireless neural plasticity: approach*

{master project}

Artificial Neural Networks



Wireless Sensors Networks



Existing approach - mapping

Find best map from ANN to WSN is NP-Hard

SDR approach – topology control

1. Low-cost SDRs (Adalm Pluto SDR)
2. Match WSN to ANN topology

⇩

1. Modify any L1&L2 parameters (modulations, Tx power, etc)
2. Link performance based on weights

*Supervisor: Dr. George Exarchakos

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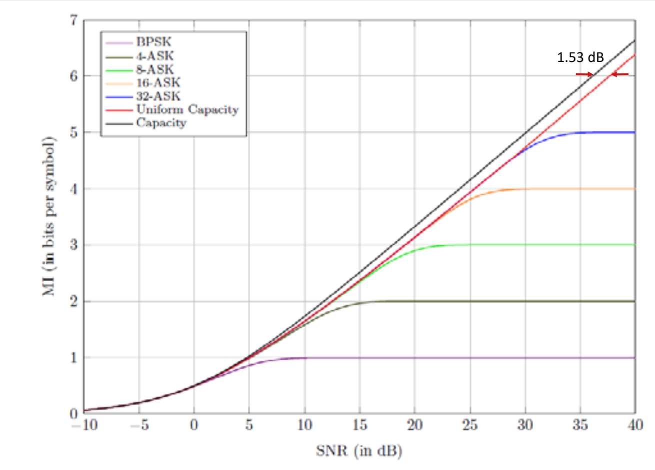
SDR in constellation shaping*

{master project}

- Constellation shaping:
  Energy efficiency enhancement scheme that improves conventional quadrature amplitude modulation schemes by transmitting low-energy signals more frequently than high-energy ones
- Integrating constellation shaping into an OFDM-based system
- Confirm the improvements observed in simulations
- Using SDR NI USRP 2900s/2920s

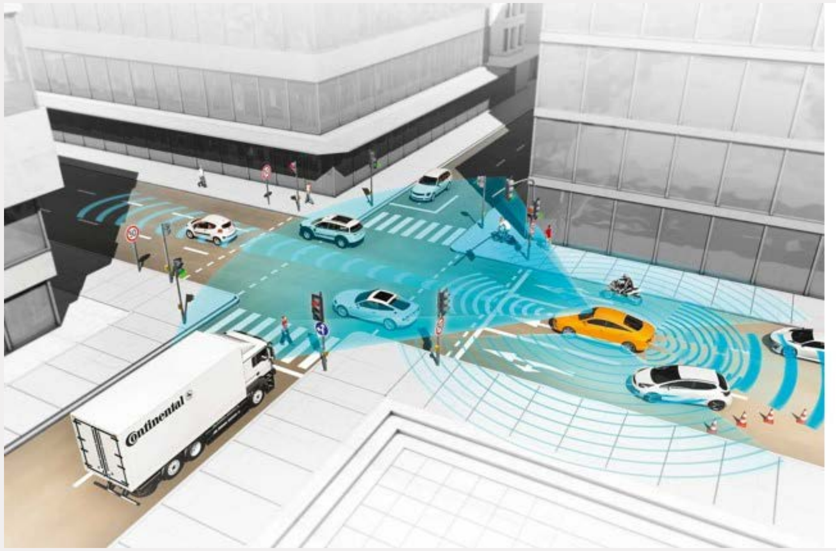


Loss in maximum achievable information rate

**Supervisor: Yunus Can Gültekin*

SDR in radar-based communication* {bachelor project}

- Realizing FMCM waveform transmission (radar) with embedded phase modulation
- FMCW radar-communication signal transmitter and receiver separately on two USRP
- In the context of i-cave project
- Advanced radar-based communication network (RADCOM) for advanced driver assistance systems (ADAS)
- Low latency data sharing for rapid coordination between radars



Supervisor: Prof. Frans Willems

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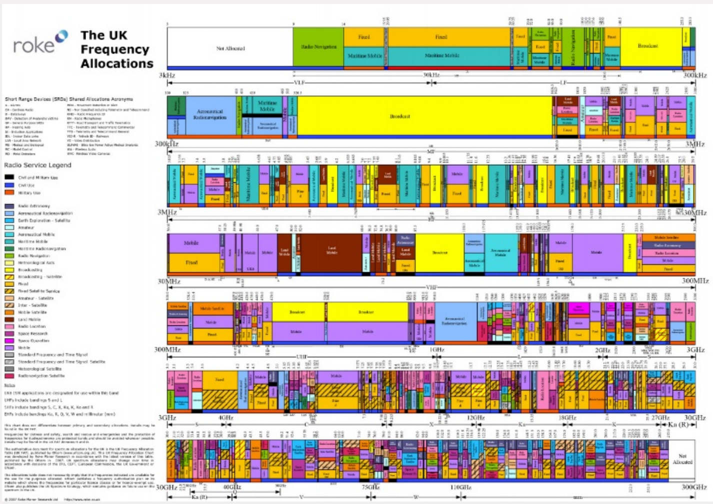
SDR for cognitive radio



Difficult to find spectrum opportunities for new wireless systems

However:

- Large geographical and temporal variations
- Large portions of the spectrum are under utilized

Problem: utilizing the allocated spectrum in the most efficient manner

Cognitive radio (CR)

- Radio changes its transmission parameters depending on the interaction with the environment
- SDRs with learning and adapting capabilities

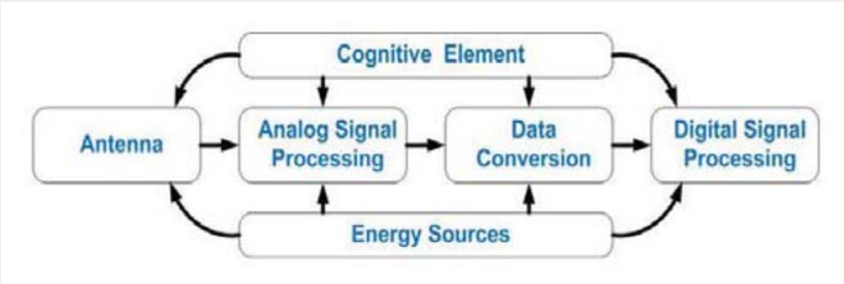
SDR for Cognitive radio

EU Project Par4CR

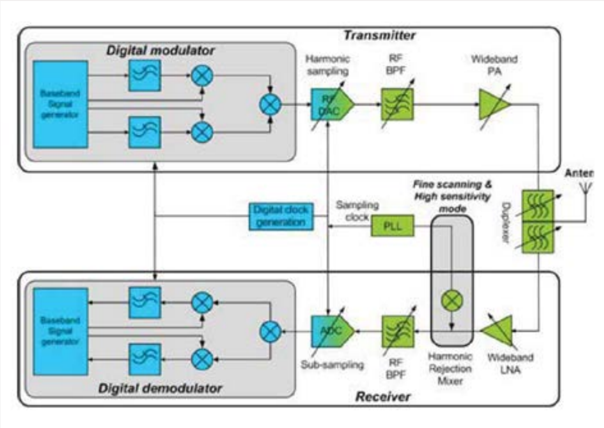
Partners: TU/e (Coordinator, Prof. Peter Baltus), NXP (France), ESIEE (France), Catena, TNO, ITE (Poland), IMST (Germany),

System, architecture and circuit design of SDR and its evolution to CR

Cognitive transceiver
from 50 MHz – 5.8 GHz



Overall system design model of the CT



General system architecture of the CT

Hoping for a flexible frequency allocation policy for above 300 GHz

SDR in Teaching

- Digital wireless communication exploration lab (master)
  - Bridging the gap between theory and practice
  - symbol synchronization, frame detection, channel estimation and equalization, etc.

NI USRP 2900

- Telecommunication networks (bachelor)
- Internet of Things (bachelor)

AD ADALM PLUTO

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Final remarks

Final remarks

- SDR of great significance to both academia and industry
- Simplification of the realization of communication protocols while enabling researchers to experiment with prototypes on deployed networks
- Increasing emphasis on programmability, flexibility, portability, and energy efficiency, in cellular, WiFi, and M2M communication.
- SDR has a good case in 5G
- Evolution towards software-defined 5G systems
- SDR essential in cognitive radio and cognitive networks
  - Desirability of not allocating frequencies in the traditional way but instead based on SDR/CR

Centre for Wireless Technology, Eindhoven