Learning to Communicate: Deep Learning based solutions for the Physical Layer of Communications [LeanCom]

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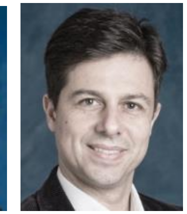
26 May 2021

LeanCom Overview

Duration: Oct 2019 – Sep 2022, Value: £860k

Why Deep Learning for comms:

- Address mathematically non-tractable problems
- Learning-based approaches to reduce complexity of known signal processing solutions

Comms particular challenges:

- Need new comms-oriented NN loss-functions / architectures
- Limited online training
- NN complexity – need lightweight and hardware-friendly NNs

Opportunities in the Comms domain:

- Good model-based solutions exist – good starting points
- Develop hybrid model-based + data-driven approaches

UCL

Duke UNIVERSITY

HUAWEI

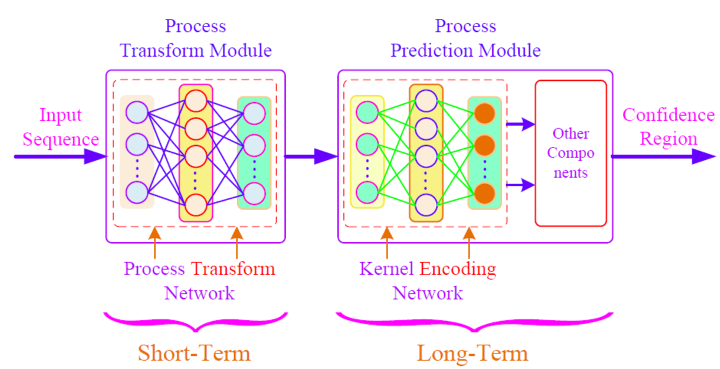
CATAPULT Digital

NEC
NEC Technologies

commnet² communications and networking

EPSRC
Engineering and Physical Sciences Research Council

Neural-Network (NN) Based Transceivers



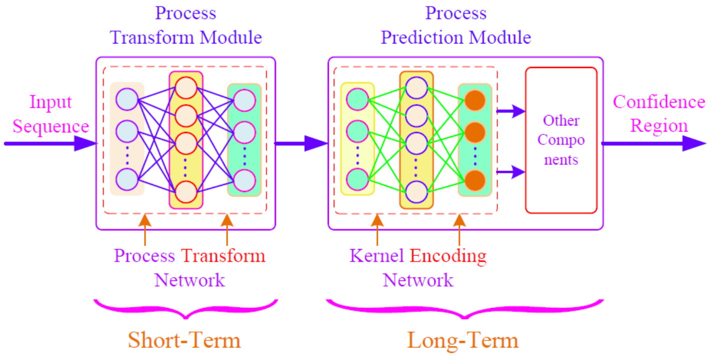
LeanCom Overview

Duration: Oct 2019 – Sep 2022, Value: £860k

LeanCom Objectives

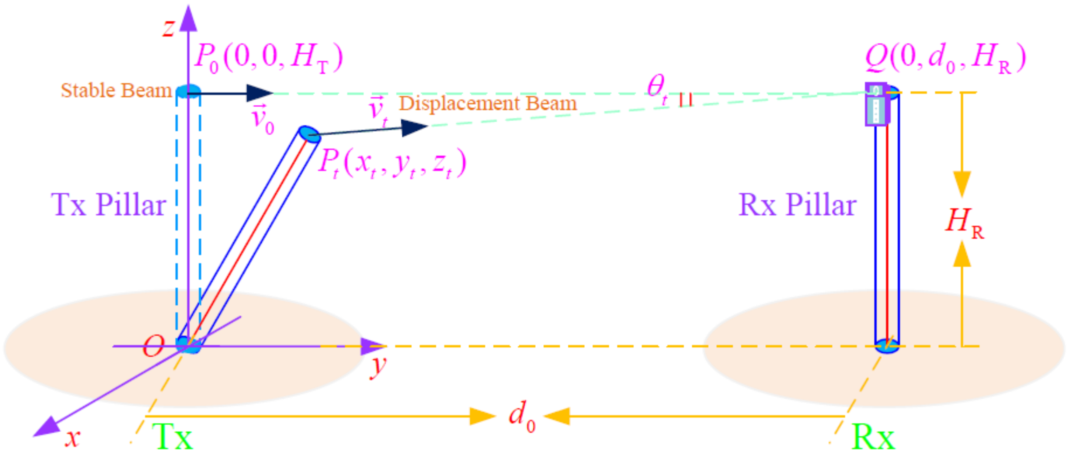
1. Establish a DL framework specifically tailored for wireless communications,
2. PHY layer transceiver designs based on NN training and optimisation - mathematically complex communication scenarios,
3. Address low-cost, low-specification devices by hardware-efficient DL-based transceivers,
4. Demonstrate DL-inspired communications by proof of concept experiments.

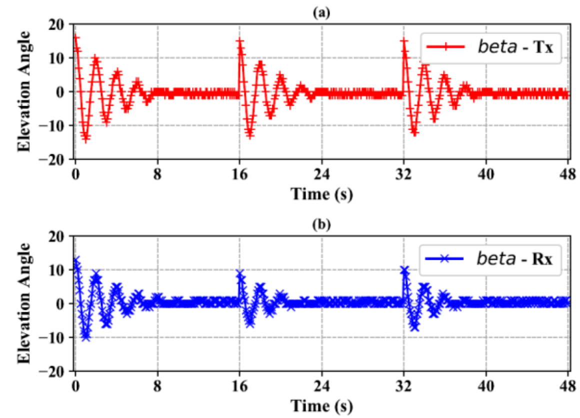
Neural-Network (NN) Based Transceivers

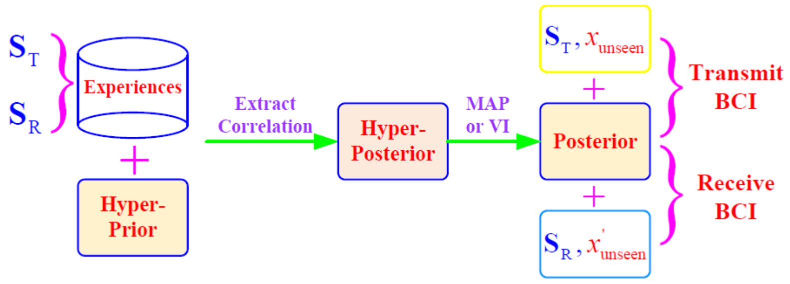


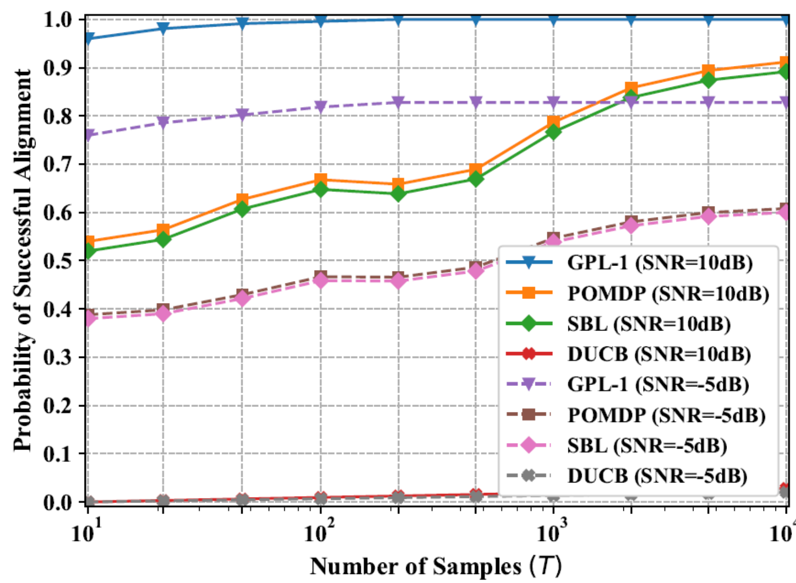
EPSRC
Engineering and Physical Sciences
Research Council

Beam prediction for Fixed Wireless Access Links





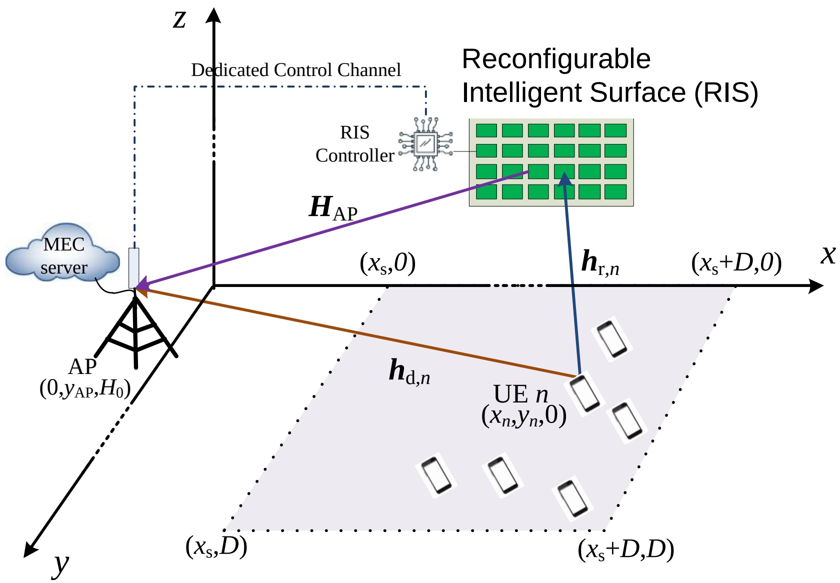


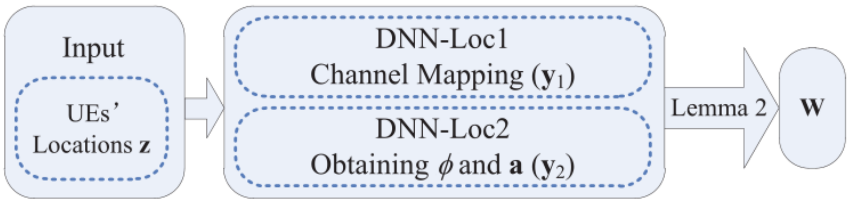


- Beam angle prediction based on geometric models
- Beam alignment with relatively **small #training samples**

J. Zhang, C. Masouros, "**Learning-Based Predictive Transmitter-Receiver Beam Alignment in Millimeter Wave Fixed Wireless Access Links**", IEEE Trans Sig. Proc., *early access on IEEExplore*

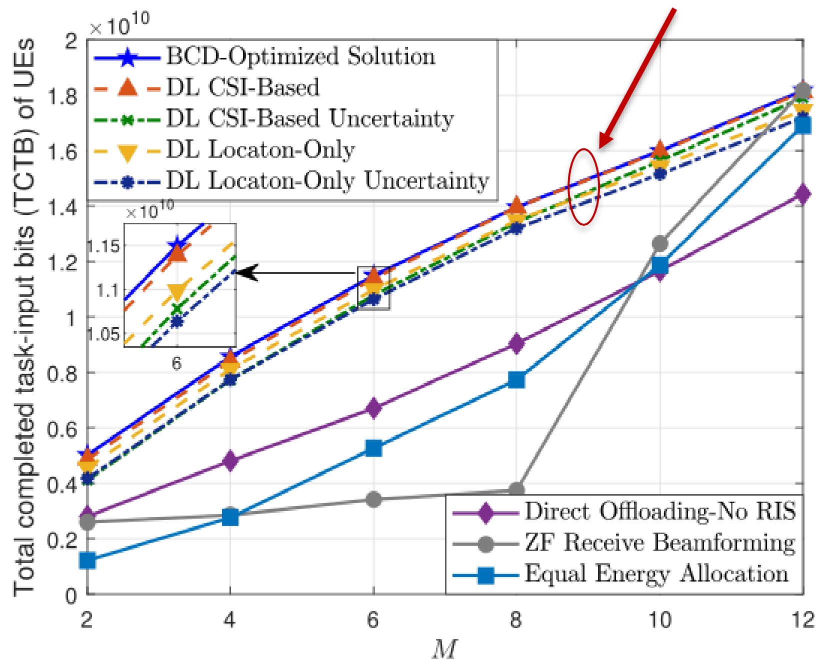
RIS aided MEC: Channel-Information based → location based





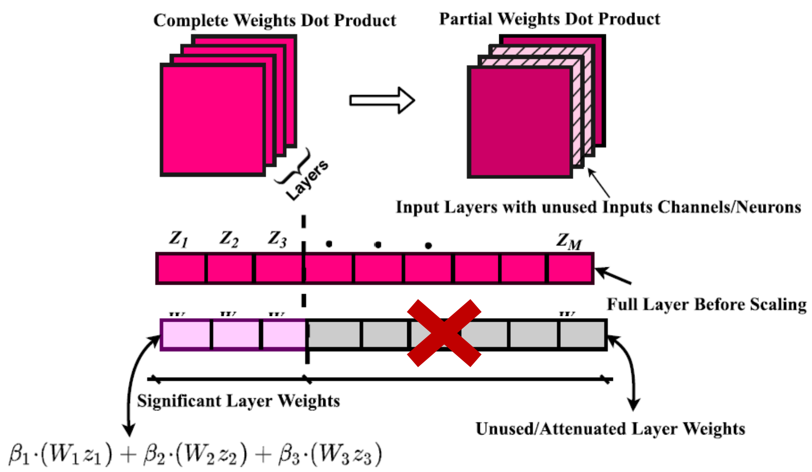
- Learning of: UE precoding + RIS precoding + AP combining
- Close to optimization-based solution **with only UE location information**, dispensing of channel estimation

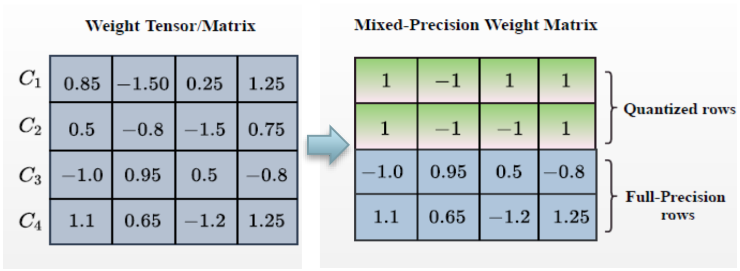
Optimization based, CSI learning-based, location based

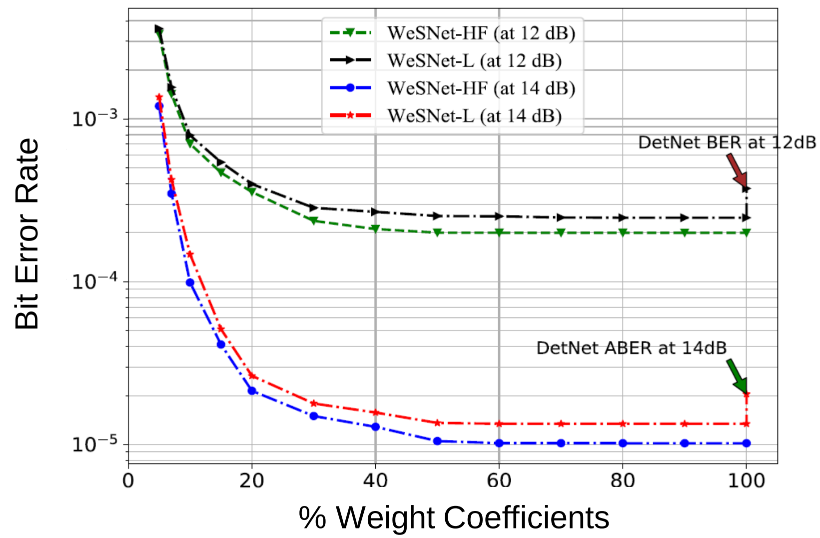


X. Hu, C. Masouros, K. K. Wong, "**Reconfigurable Intelligent Surface Aided Mobile Edge Computing: From Optimization-Based to Location-Only Learning-Based Solutions**", IEEE Trans Comms, *early access on IEEExplore*

Complexity-scalable NNs for Multi-antenna detection







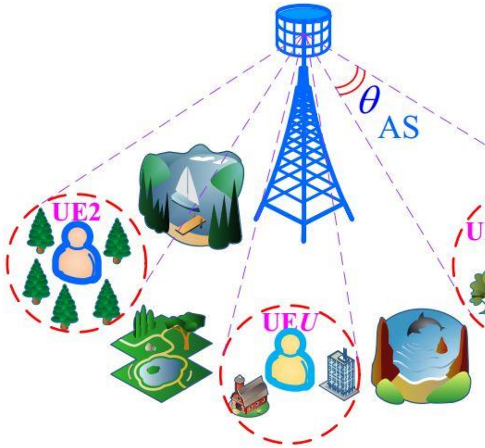
- Scaling of ‘non-significant’ weights to **reduce dimension/complexity of NNs**
- **Finite-resolution (few-bit) NNs**
- Close to optimal performance with less than 50% of weights

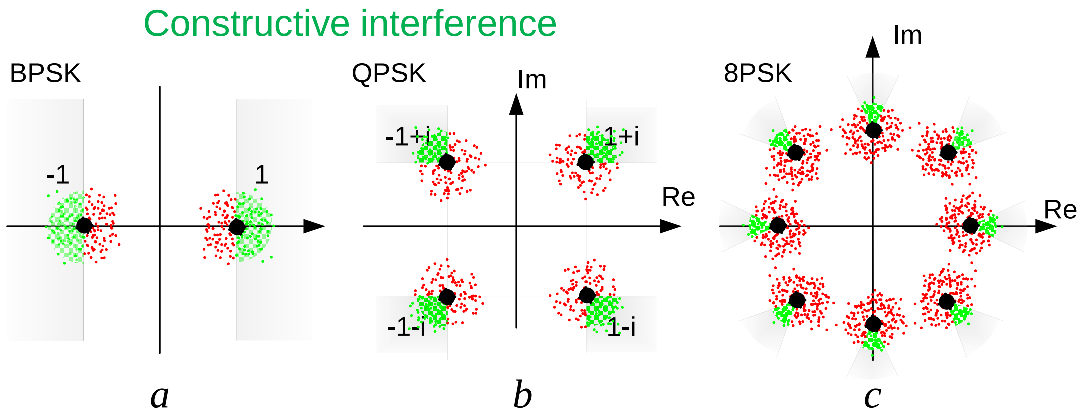
⇩ Memory consumption
⇩ Complexity ✓ Hardware Friendly

A. Mohammad, C. Masouros, I. Andreopoulos, “**Complexity-Scalable Neural Network Based MIMO Detection With Learnable Weight Scaling**”, IEEE Trans. Comms., vol. 68, no. 10, pp. 6101-6113, Oct. 2020

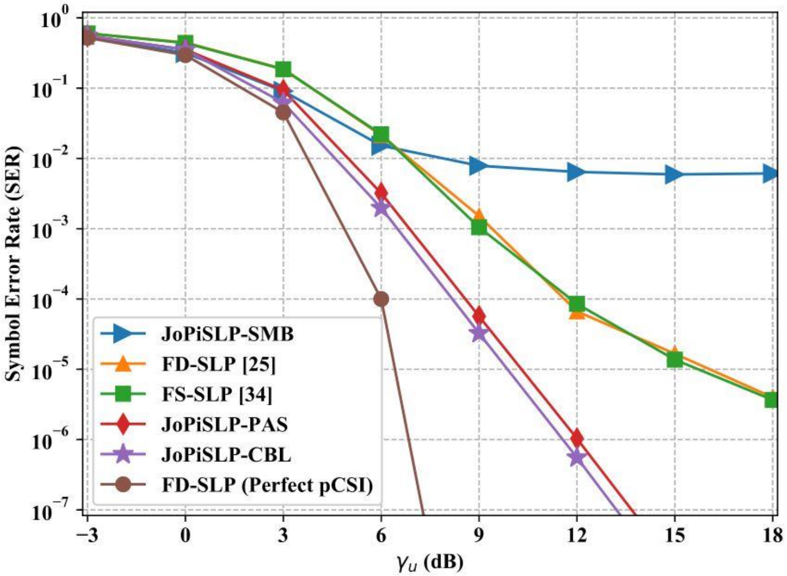
A. Mohammad, C. Masouros, I. Andreopoulos, “**A Memory-Efficient Learning Framework for Symbol Level Precoding with Quantized NN Weights**”, IEEE Trans. Comms., *under review*

Joint Precoding and Channel Sparsification





$$\begin{aligned} \min_{\mathbf{d}} \quad & \|\mathbf{F}\mathbf{d}\|_2^2 + \rho\|\mathbf{d}\|_1 \\ \text{s.t.} \quad & \left|\mathrm{Im}(\bar{\mathbf{h}}_u^{\mathrm{H}}\mathbf{F}\mathbf{d}e^{-j\xi_u})\right| \le \left(\mathrm{Re}(\bar{\mathbf{h}}_u^{\mathrm{H}}\mathbf{F}\mathbf{d}e^{-j\xi_u}) - \gamma_u\right)\cdot \\ & \tan(\pi/K_u),\ (\forall u \in \mathcal{U}). \end{aligned}$$



- **Two things at once**: a) channel sparsification, b) Precoding for interference exploitation
- Reduced CSI approach, close to full CSI based precoding

J. Zhang, C. Masouros, “**A Unified Framework for Precoding and Pilot Design for FDD Symbol-Level Precoding**”, IEEE Trans Comms., *under review*

Net-Zero Energy Communications

Energy-autonomous Portable Access-Points



- CO^2 emissions and OPEX
- Power grid infrastructure

- Renewable Sources + Energy Harvesting
- Portable Base Stations
- UAVs

UCL

NOKIA Bell Labs

The American College of Greece Pierce Deree Alba 1875

University of Cyprus

LYRA ELECTRONICS

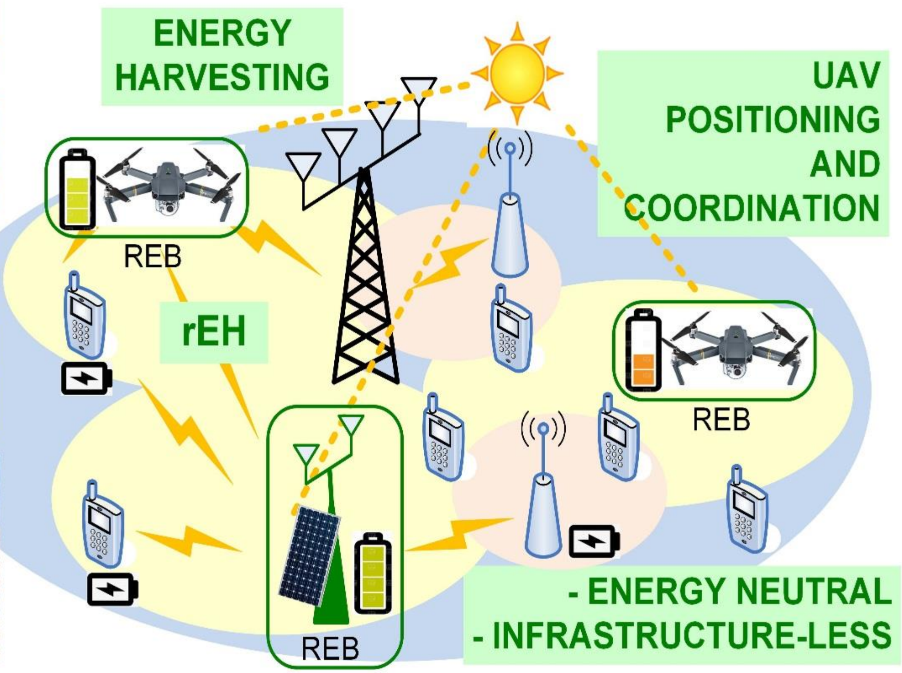
MANCHESTER 1824 The University of Manchester

cnrs

AALBORG UNIVERSITY DENMARK

RIO SYSTEMS





HORIZON 2020

Innovative Training Network
Oct 2018 – Sep 2022 (€4.2m)

http://painless-itn.com/

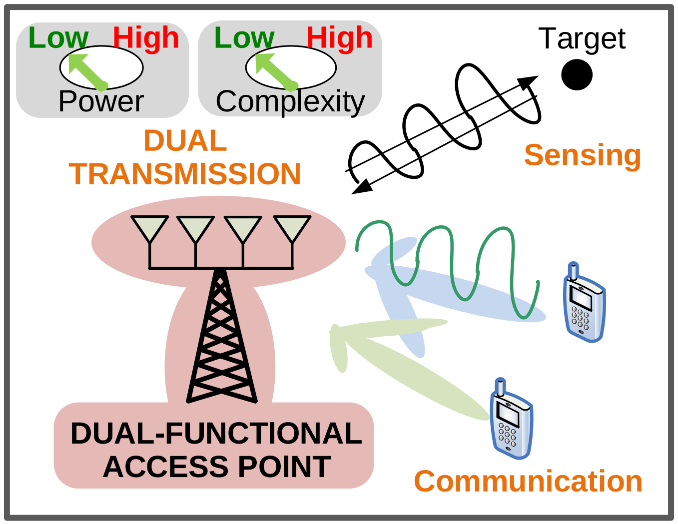
Painless ITN

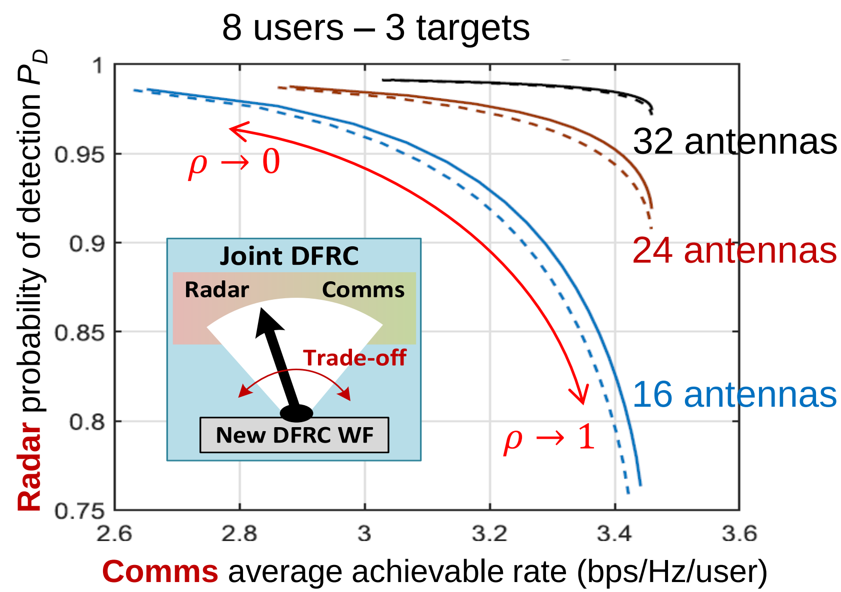
@PainlessITN

Efficient use of spectrum
Integrated Sensing and Communications (ISAC)

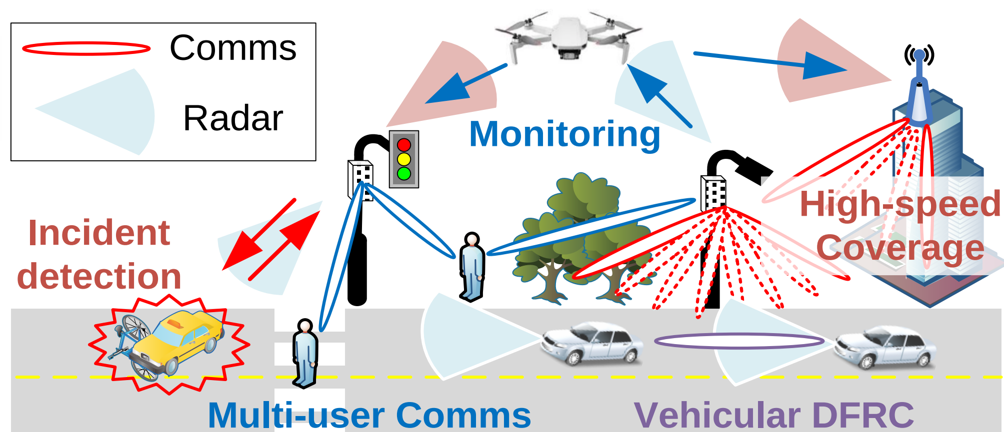


Spectrum Sharing → Dual Transmission





Smart-cities sensing through 5G dense cellular infrastructure



Part of UDRC Project
Mar 2019 – Dec 2021 (£1m)

Marie Curie Fellowship
Nov 2018 – Oct 2020 (£160k)

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Net-Zero Energy Comms

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ISAC

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- F. Liu, L. Zhou, C. Masouros, A. Li, W. Luo, A. Petropulu “**Toward Dual-functional Radar-Communication Systems: Optimal Waveform Design**”, IEEE Trans. Sig. Proc., vol. 66, no. 16, pp. 4264-4279, Aug.15, 15 2018

Thank you

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