UNIVERSITÀ
DEGLI STUDI
DI PADOVA

SIGNET

Department of Information Engineering (DEI)
Master degree on ICT for Internet and Multimedia Engineering (MIME)

Presentation of the Research Activities of Prof. Michele Zorzi's Group

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Introduction

- Wireless networks are at the basis of what we do, daily.
- In a few years, everything will be connected, with people, things, vehicles and robots seamlessly interacting over future networks.

SIGNET

The SIGNET research team is active on the *SIGNal processing and NETworking* research challenges, with a solid track record in the area of wireless networking.

Prof. Michele Zorzi is the supervisor of 6 PhD students, 3 post-doctoral researchers and 1 engineer within the SIGNET group.

GOAL: Identify possible topics for MS final course projects and theses, internship, and other research opportunities in the areas of wireless networks.

- Future Wireless Nets
- Connecting Everything
- Underwater Networks

Today's meeting

1. Presentation of active projects for your theses/internship
2. Presentation of our research topics:
   a. **Future Wireless Networks**
      - 5G research
      - Looking forward to 6G
      - DEMO: the mmWave ray tracer

   b. **Connecting Everything**
      - Towards Internet of Things
      - Towards Autonomous Cars
      - DEMO: the CARLA simulator and the automotive sensors

   c. **Underwater Networks**
      - How to communicate underwater?
      - Research activities
      - Real field experiments
3. International opportunities for your theses
4. Question time

Collaborations and active projects

Our group is currently collaborating with several industrial and academic partners

NIST National Institute of Standards and Technology U.S. Department of Commerce

orange

Fraunhofer

AT&T

TOYOTA

{SYMBIOSIS}

EUROPEAN DEFENCE AGENCY

Institute for the Wireless Internet of Things at Northeastern University

HPA Hamburg Port Authority

RoboVaaS

SCIENCE TO SHAPE THE FUTURE OF THE ARMY · ARMY RESEARCH OFFICE · 1951

HUAWEI

NYU WIRELESS

TUHH

NOKIA Bell Labs

W&M

European Commission

Strong local support

- The theses/internships we propose are related to the daily research of the Ph.D. students and postdocs here in Padova
  - they will support and coordinate your activities

- Many former master thesis students are now further developing their research as Ph.D. students, borsisti di ricerca

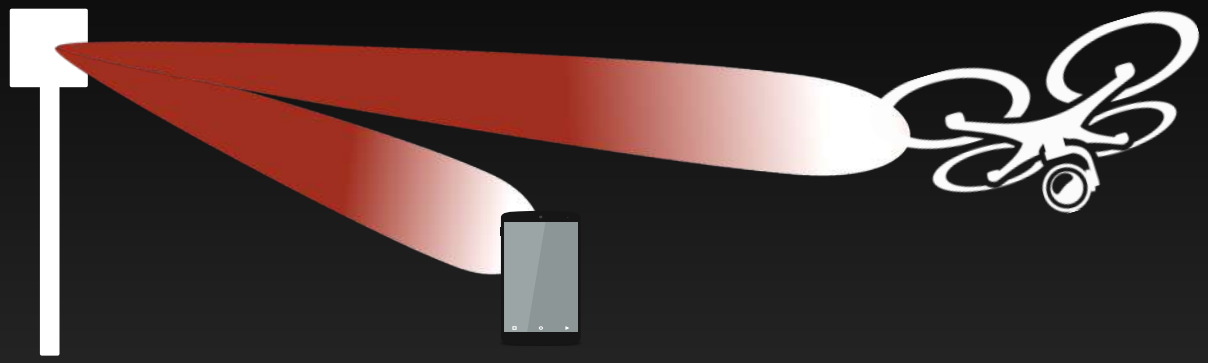
- Possibility for internships in Wireless & More
  - spin-off founded by me and Prof. Lorenzo Vangelista
  - underwater and IoT

http://www.wirelessandmore.it/

Future Wireless Networks

5G is a revolutionary technology that will be in your pocket in a few months

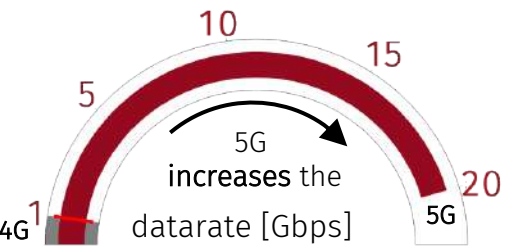
- the main novelty is the communication at millimeter wave frequencies (30-300 GHz)

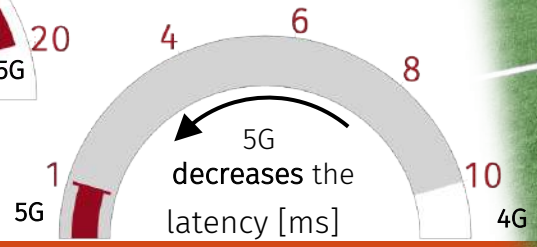


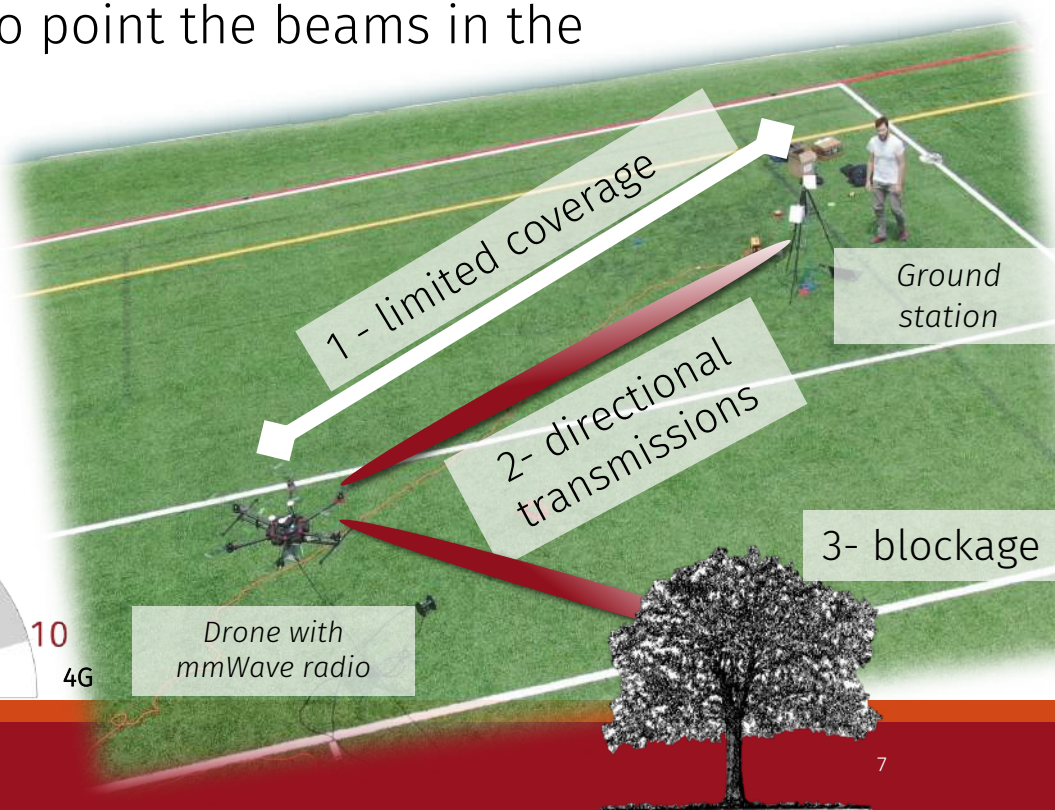
The research community has already started studying **6G**!

MmWaves are great: large bandwidth, ultra-high data rates, but they also present a number of challenges

- High propagation loss, which can be compensated with directional transmissions, in which focused beams are used to increase the communication range
- The endpoints, however, need to point the beams in the same direction
- MmWave signals are easily blocked



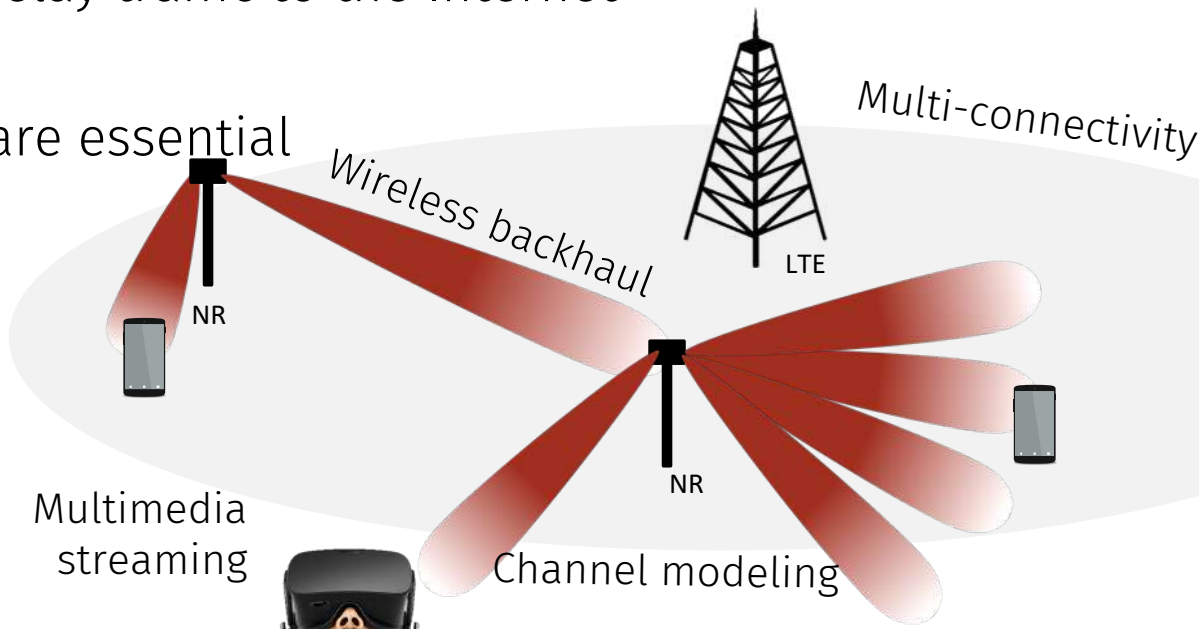




Our 5G research

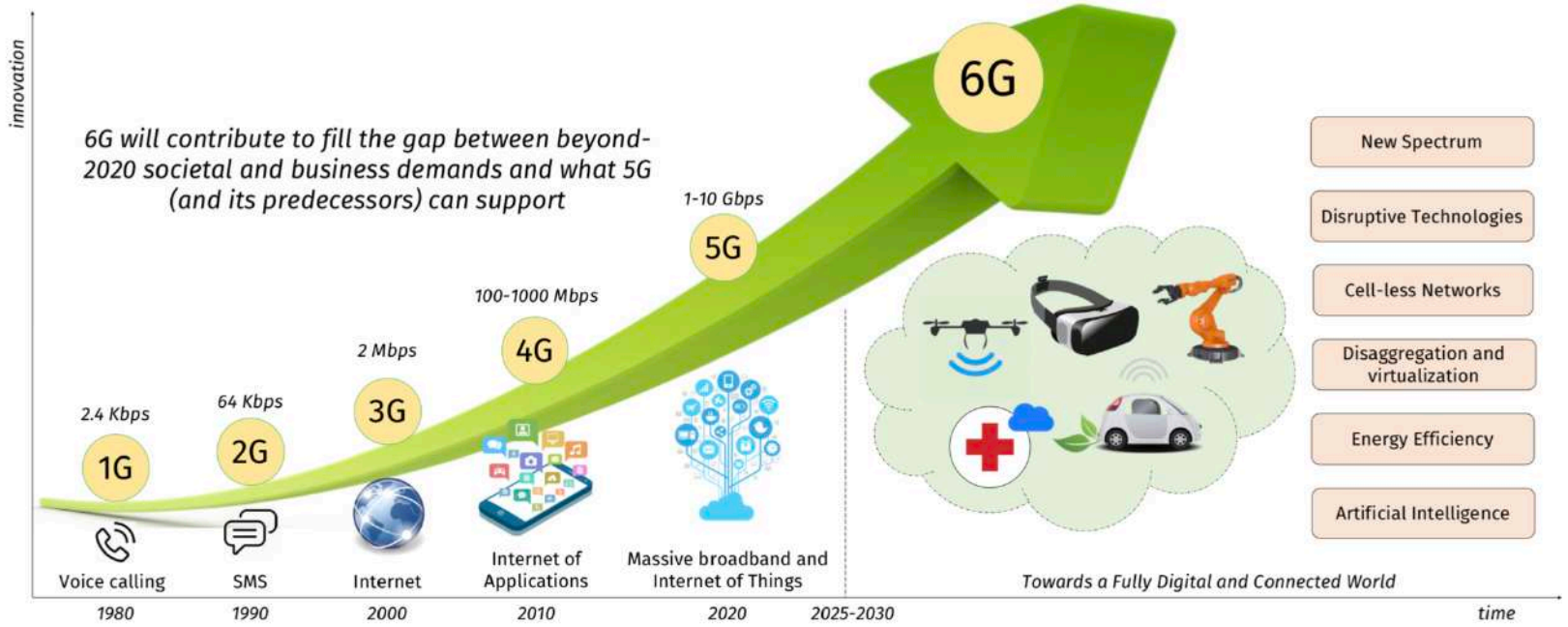
We study network solutions to overcome the limitations of mmWaves for cellular networks (3GPP NR) and public safety

- Multi-connectivity
  Exploit links at different frequencies to make the network more robust
- Wireless backhaul
  Re-use mmWaves also to relay traffic to the Internet
- Channel modeling
  Accurate channel models are essential for meaningful simulation results
- Multimedia streaming
  Study streaming performance on 5G links



Looking forward to 6G

- From 1G to 5G, each generation of mobile technology has tried to meet the **needs** of network operators and final consumers.
- The rapid development of **data-centric** and **automated processes** may exceed even the capabilities of emerging 5G systems, thereby calling for a new (sixth) wireless generation



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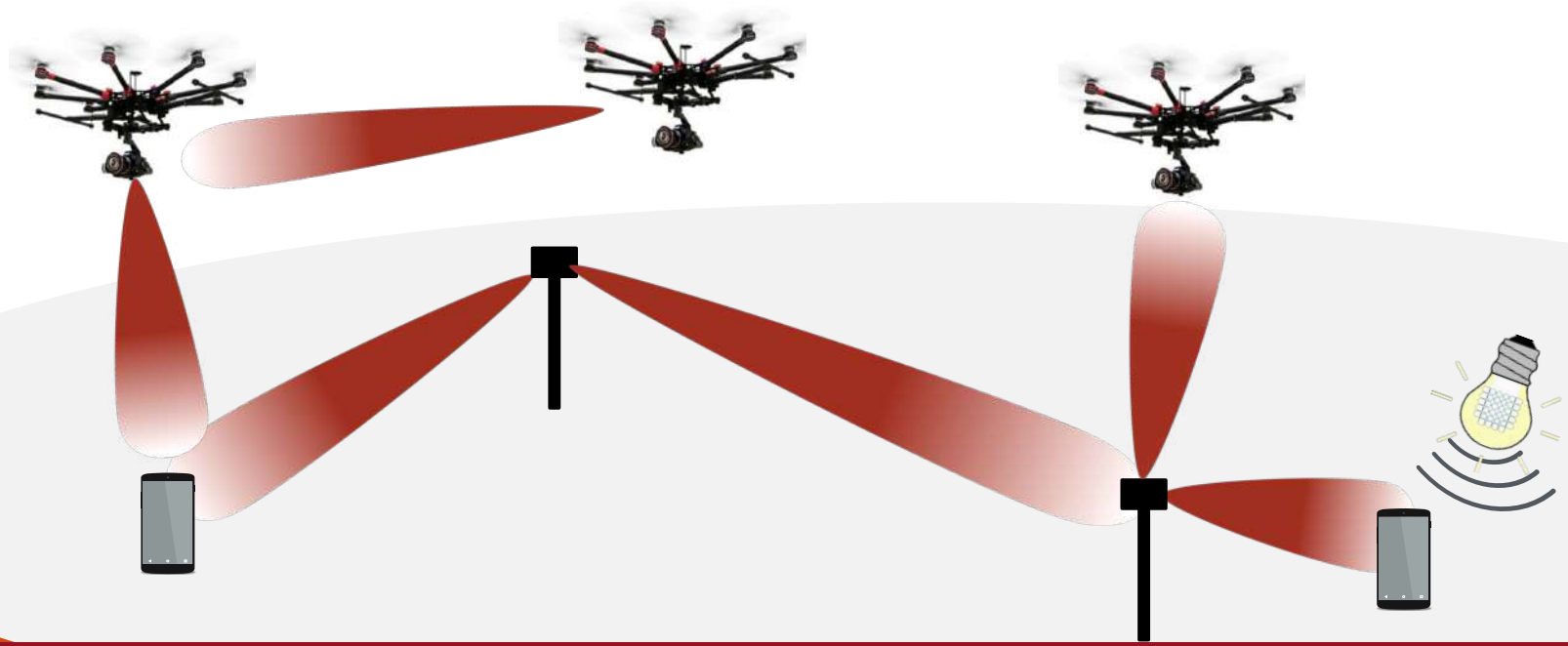
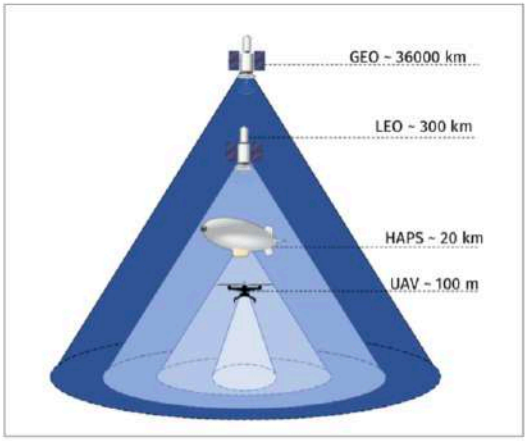
Looking forward to 6G

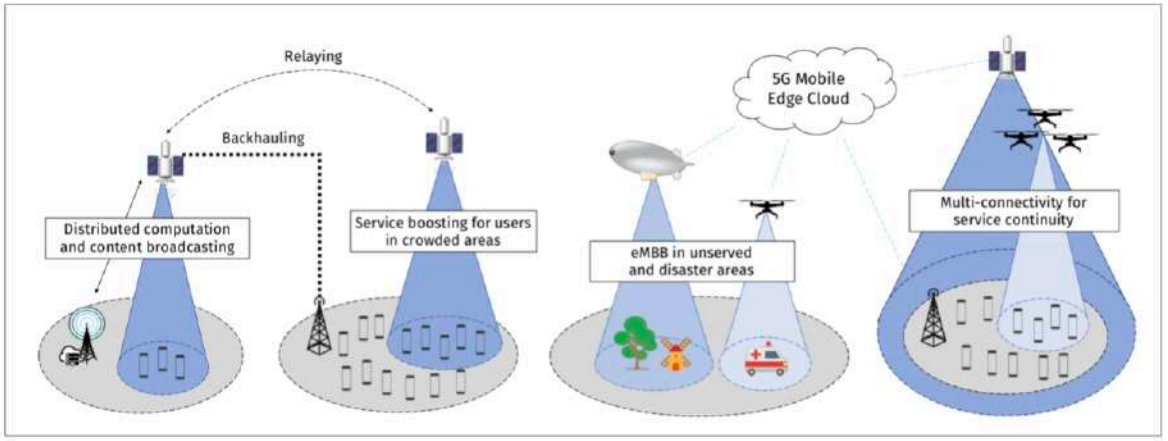
Moving up:

- 3D networks and integration of **drones** and **satellites** in mobile networks
- Even higher frequencies: visible light and **terahertz**



Satellites and mmWaves





Synchronization

Service continuity

HARQ and modulation

Spectrum co-existence

Latency constraints

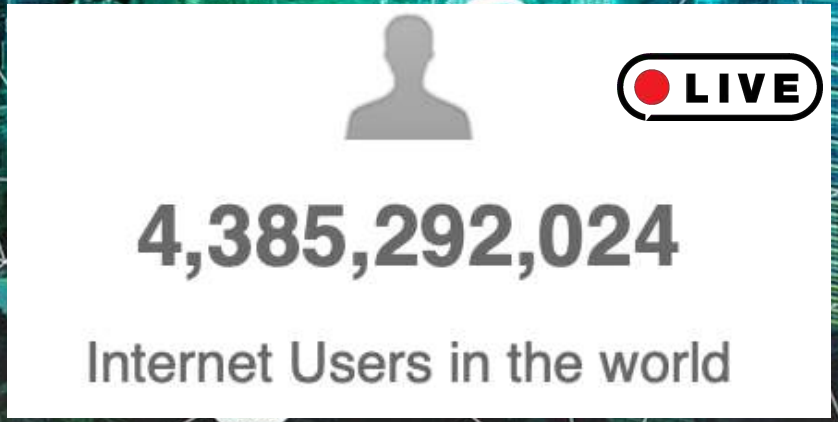
MAC/RLC procedures

Connecting Everything

It's not all about cellular networks…

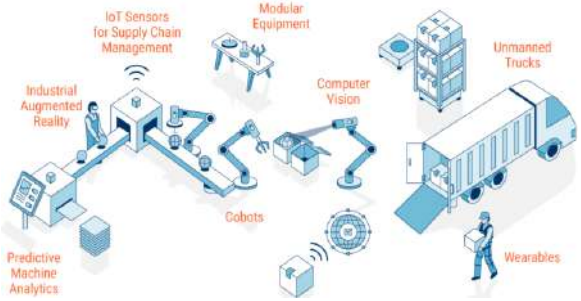
By 2035, there will be more that 35 BILLION connected devices…

How can we support such large-scale connectivity environment?

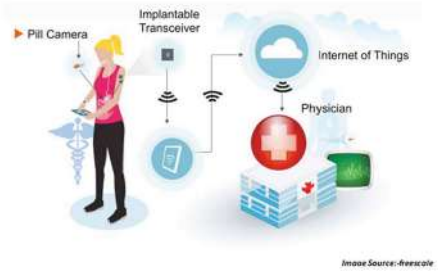


Internet of Things (IoT)

Research on analytical tools and technologies to achieve **Ultra-Reliable & Low-Latency Communications (URLLC)** for monitoring and control in Industrial Internet of Things (IIoT) and future smart cities providing the reliable infrastructure to connect smart devices.



Smart Factory



Healthcare

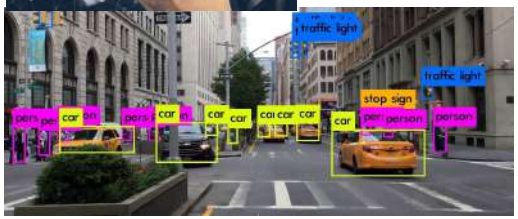
Agritech

Smart Cities

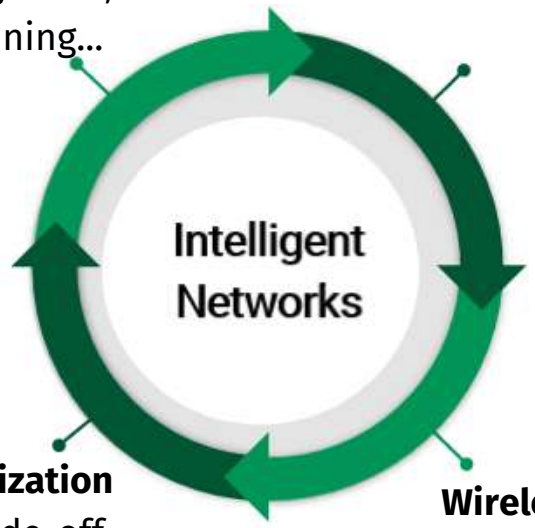
And more...

Wireless Intelligence

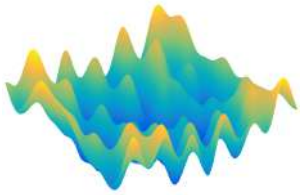
Artificial Intelligence
Perception,
Speech and
Object Recognition,
Control and Planning...



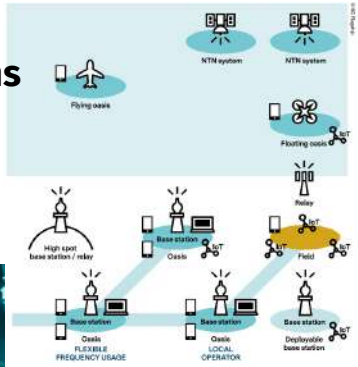
Mobile Devices
UAVs,
phones, vehicles,
sensors...



Network Optimization
Reliability/Latency trade-off,
Adaptive Coding
and Modulation,
Resource Allocation,
Distributed and Federated
Learning...



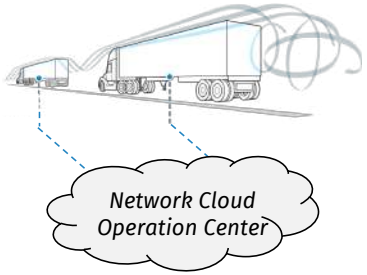
Wireless Communications
URLLC, Extreme
Environments, Remote
Areas...



Towards Autonomous Cars

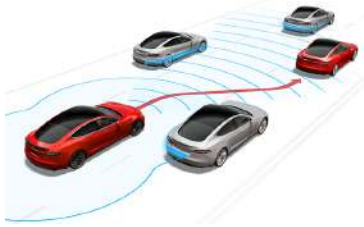
Advances in the automotive industry have opened the potential for Connected and Autonomous Vehicles (CAVs) as a means to offer **safer** and **more efficient** driving.

PLATOONING
(Cooperative driving, information sharing, remote driving control)

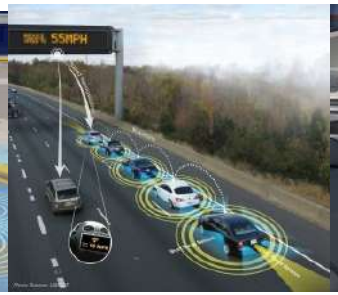


EXTENDED SENSORS
(Sensor data sharing, video sharing, cooperative perception)

ADVANCED DRIVING
(Cooperative collision avoidance, object recognition/classification)



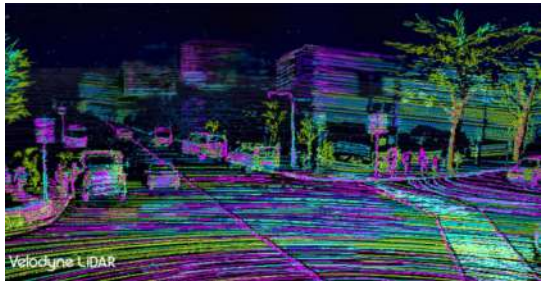
INFOTAINMENT
(Video streaming, AR/VR, online gaming, web browsing)



Research Challenges

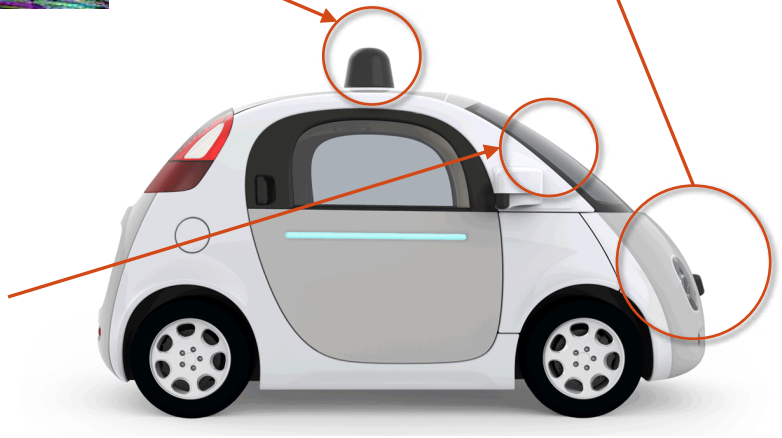
> The number of sensors per vehicle is foreseen to rise to more than **200** by 2020
> N. Lu, et al., "Connected Vehicles: Solutions and Challenges," IEEE Internet of Things Journal, vol. 1, no. 4, pp. 289–299, Aug 2014.

LiDAR



THERMAL CAMERA

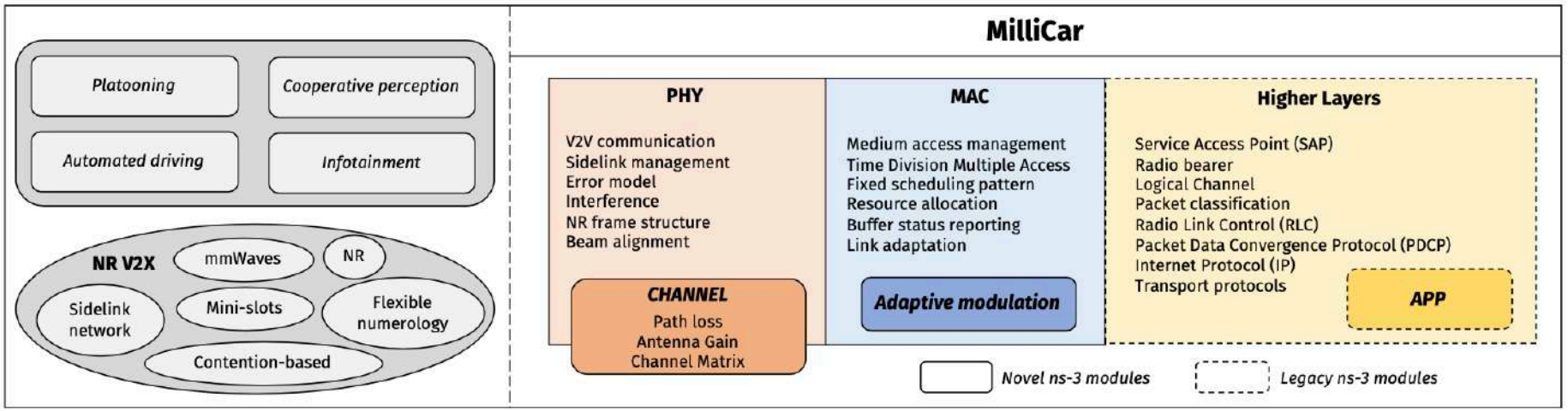
VIDEO CAMERA

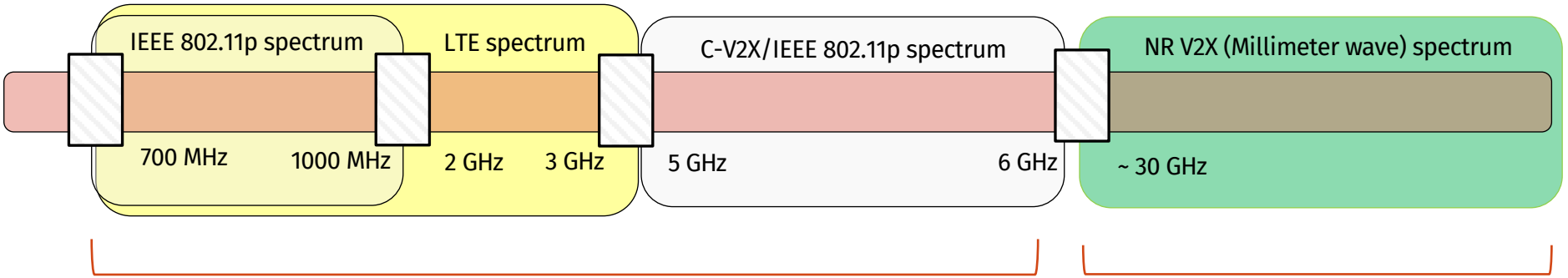


Research Challenges

- WHAT TO TRANSMIT?
- WHERE TO TRANSMIT?
- WHEN TO TRANSMIT?
- HOW TO TRANSMIT?

HOW to Transmit?

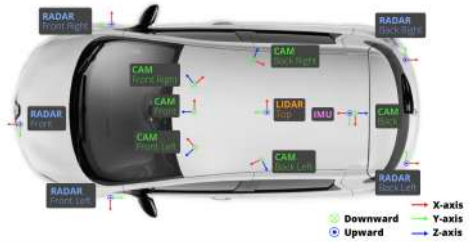


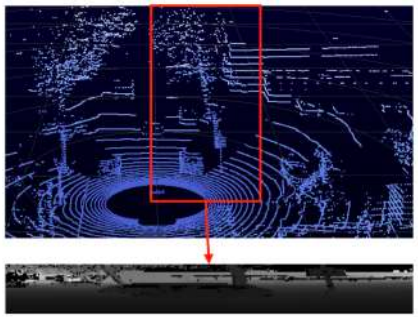


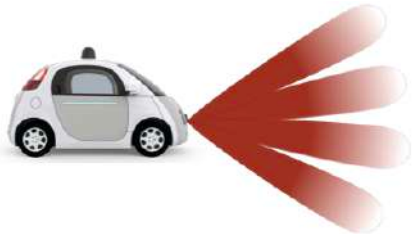
LIMITED DATA RATE

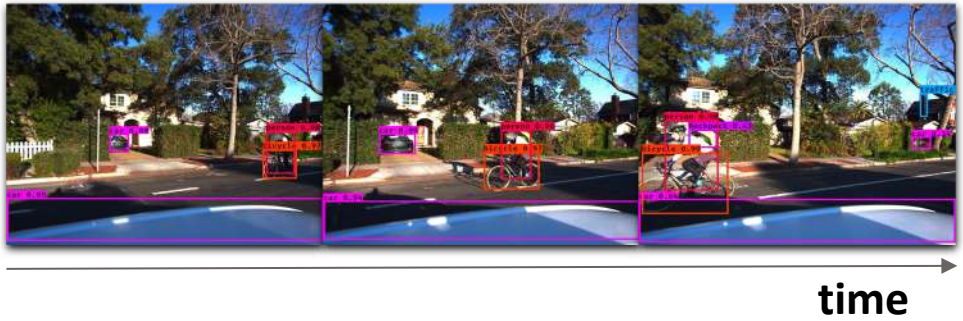
VERY LARGE BANDWIDTH
BUT… **will it work?**

WHAT to Transmit







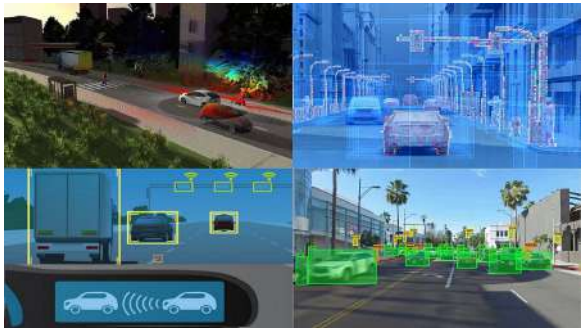


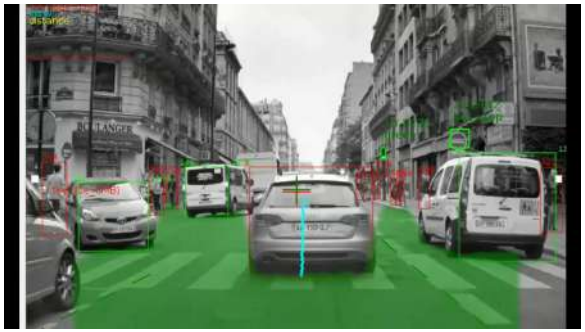
OPEN CHALLENGES

- Sensor Fusion
- Object Detection
- Object Classification
- Data Compression
- Data Transmission
- Value of Information

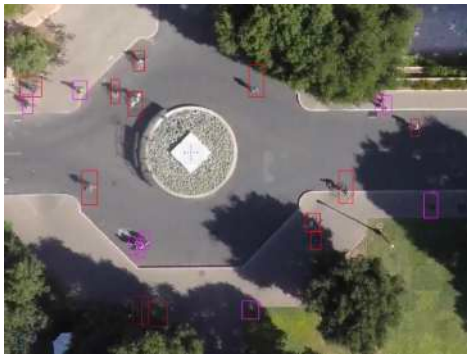
WHAT to Transmit

AUTONOMOUS DRIVING

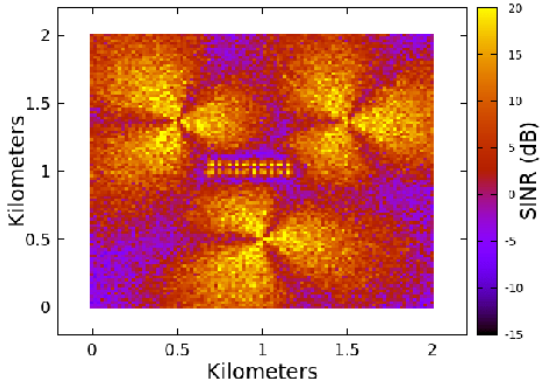


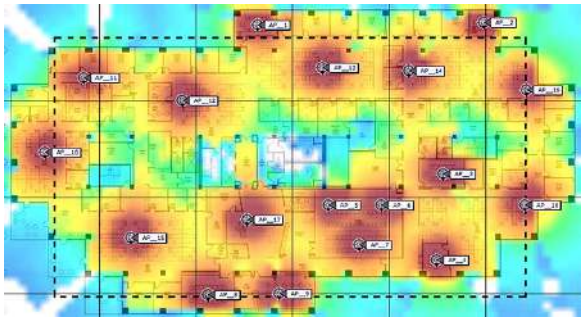


AUTONOMOUS DRIVING from the **SKY**



Channel-Aware Autonomous Driving

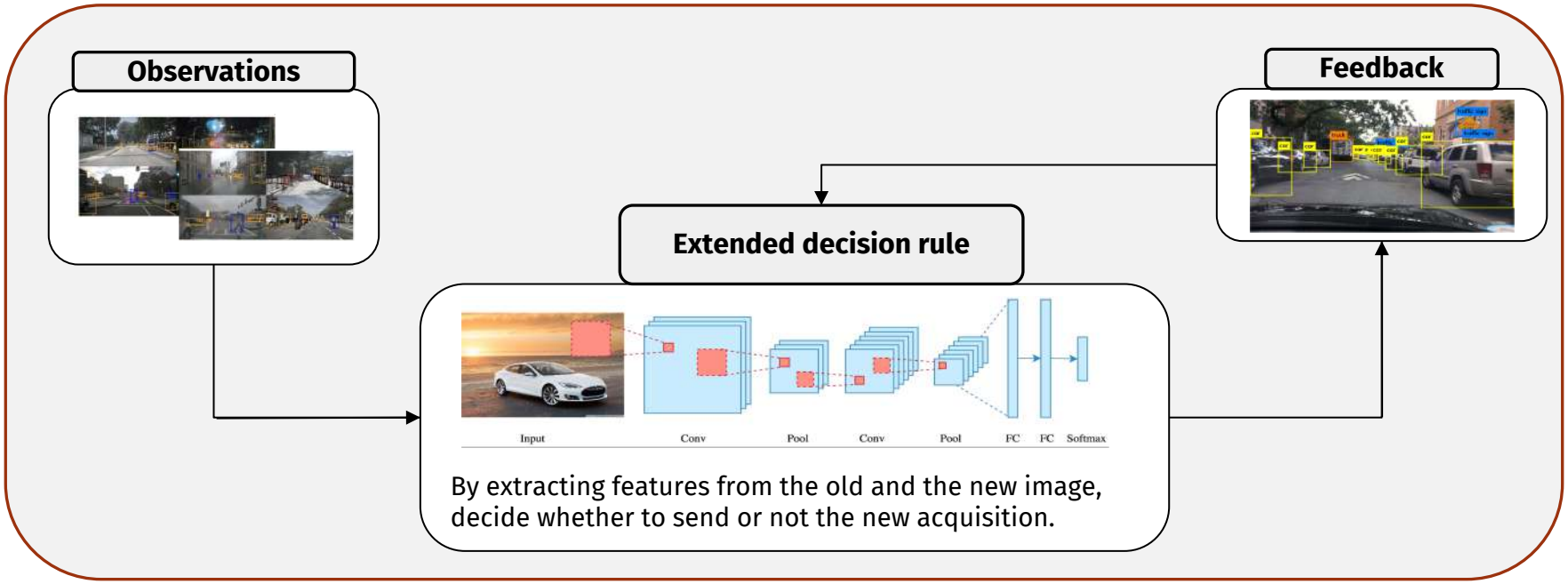


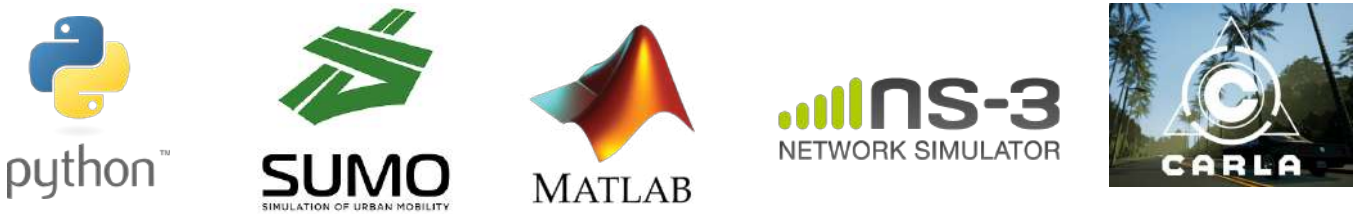


ENVIRONMENT MAP → ENVIRONMENT **RADIO** MAP → FUTURE of the ENVIRONMENT RADIO MAP → GET APPLICATION KPIs → EVALUATE QoS → TAKE COUNTERMEASURES

Machine Learning

- Reroute
- Change traffic patterns
- Change scheduer
- Change frequency


Observations
Feedback
Extended decision rule
Input
Conv
Pool
Conv
Pool
FC
FC
Softmax
By extracting features from the old and the new image, decide whether to send or not the new acquisition.


python
SUMO
SIMULATION OF URBAN MOBILITY
MATLAB
ns-3
NETWORK SIMULATOR
CARLA

Underwater Networks

Underwater sensors and vehicles cooperate to collect data

- Communication in this environment is very challenging

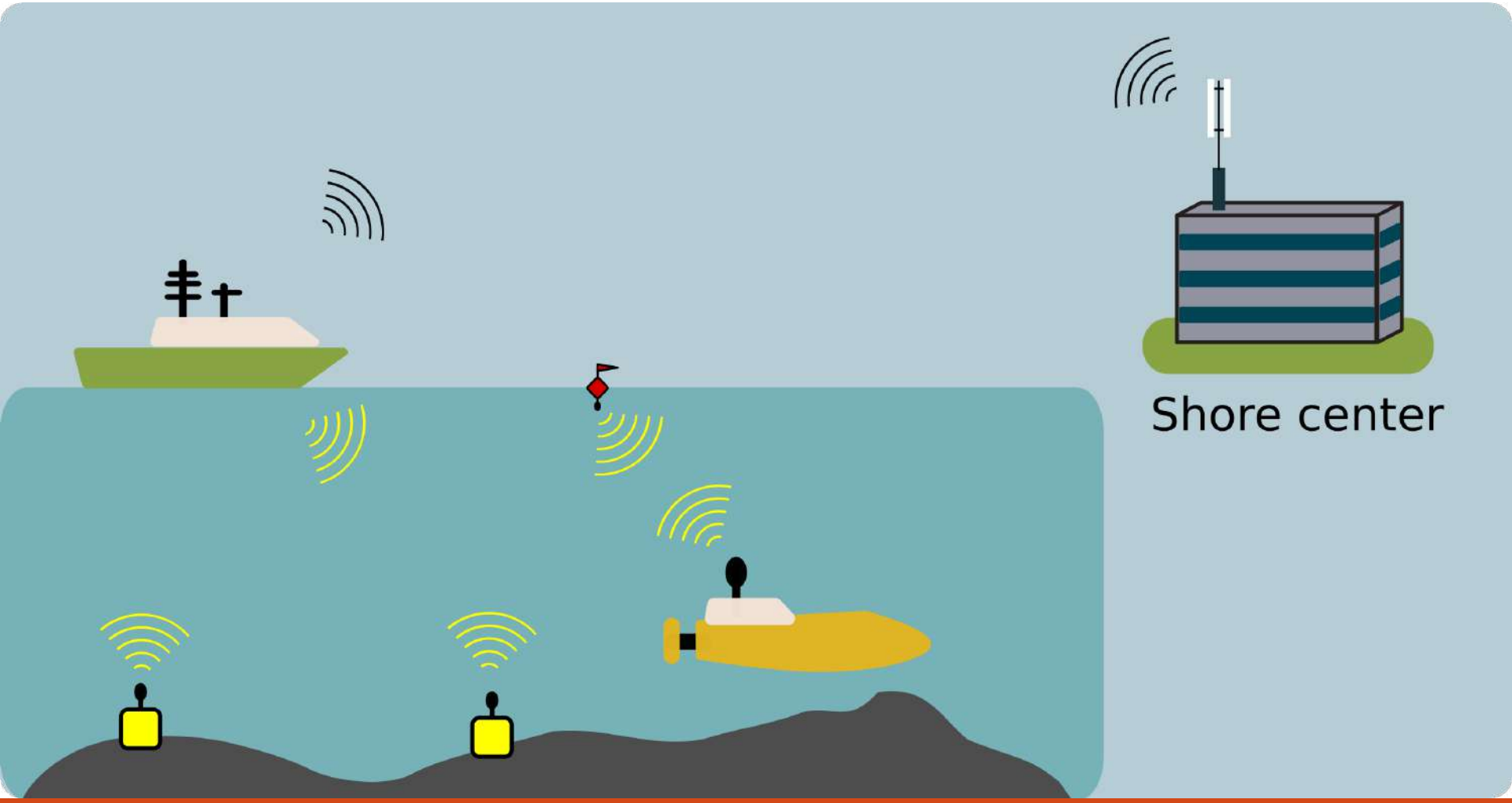
Overview

Military applications
- Coastal surveillance
- Anti-Torpedo systems

Environment monitoring
- Tsunami prevention
- Seabed erosion

Industrial application
- Pipelines inspection
- Divers support

Smartport

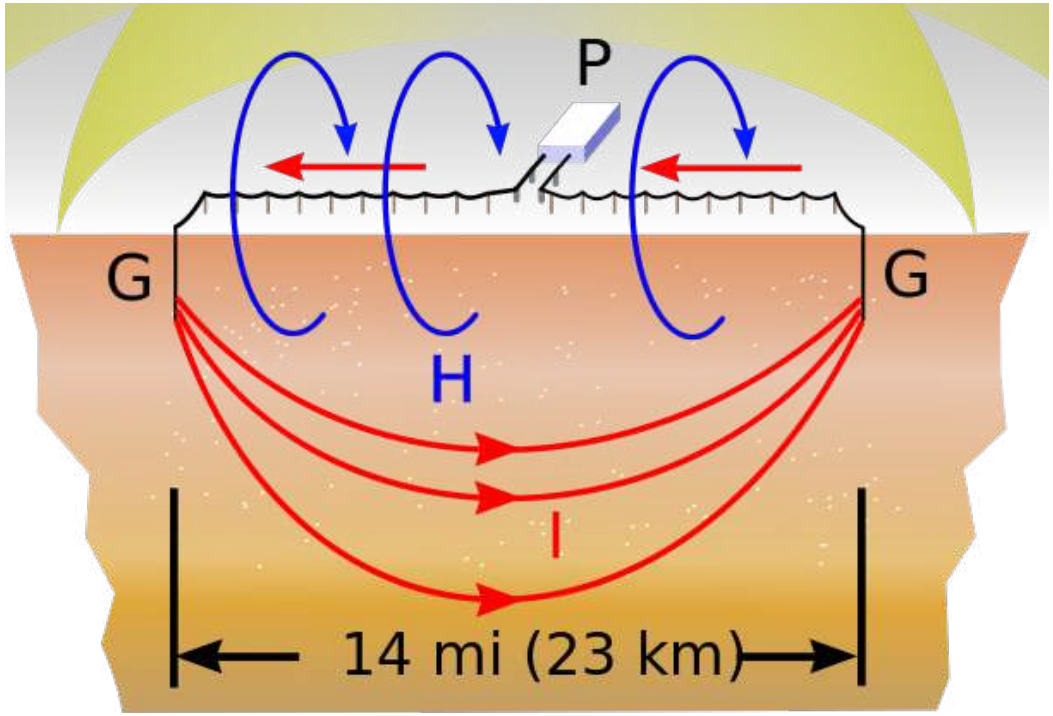


WiFi works only for **few centimeters**

VLF (3 – 30 kHz) **range** up to **20 meters**, **300 b/s**

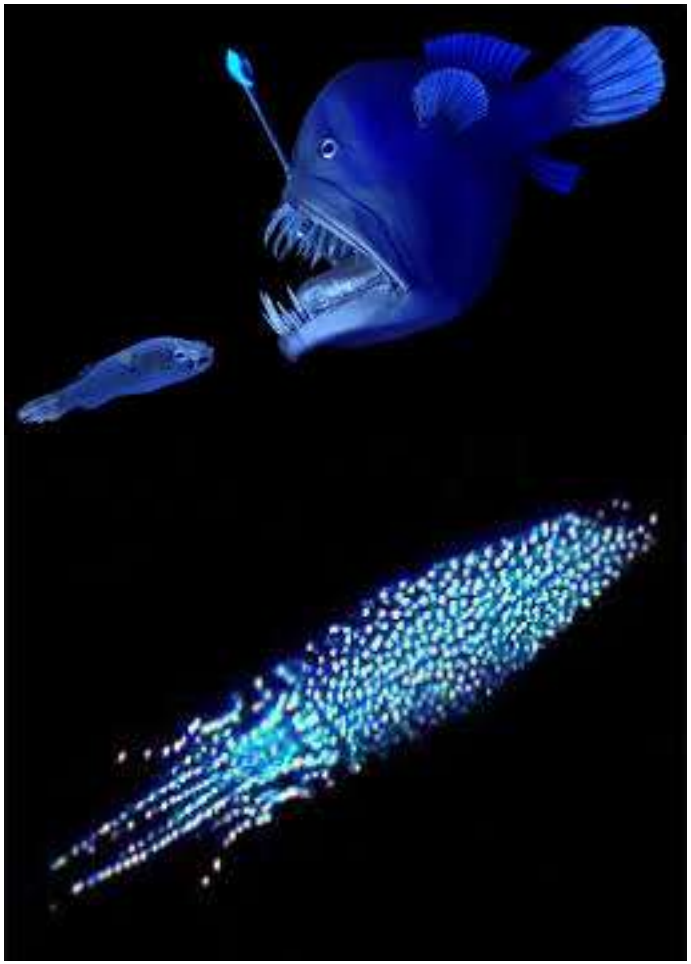
ELF (3 Hz – 300 Hz) **range** up to **several miles**, **1 b/s**.

Drawback: the size..



So… how to communicate?

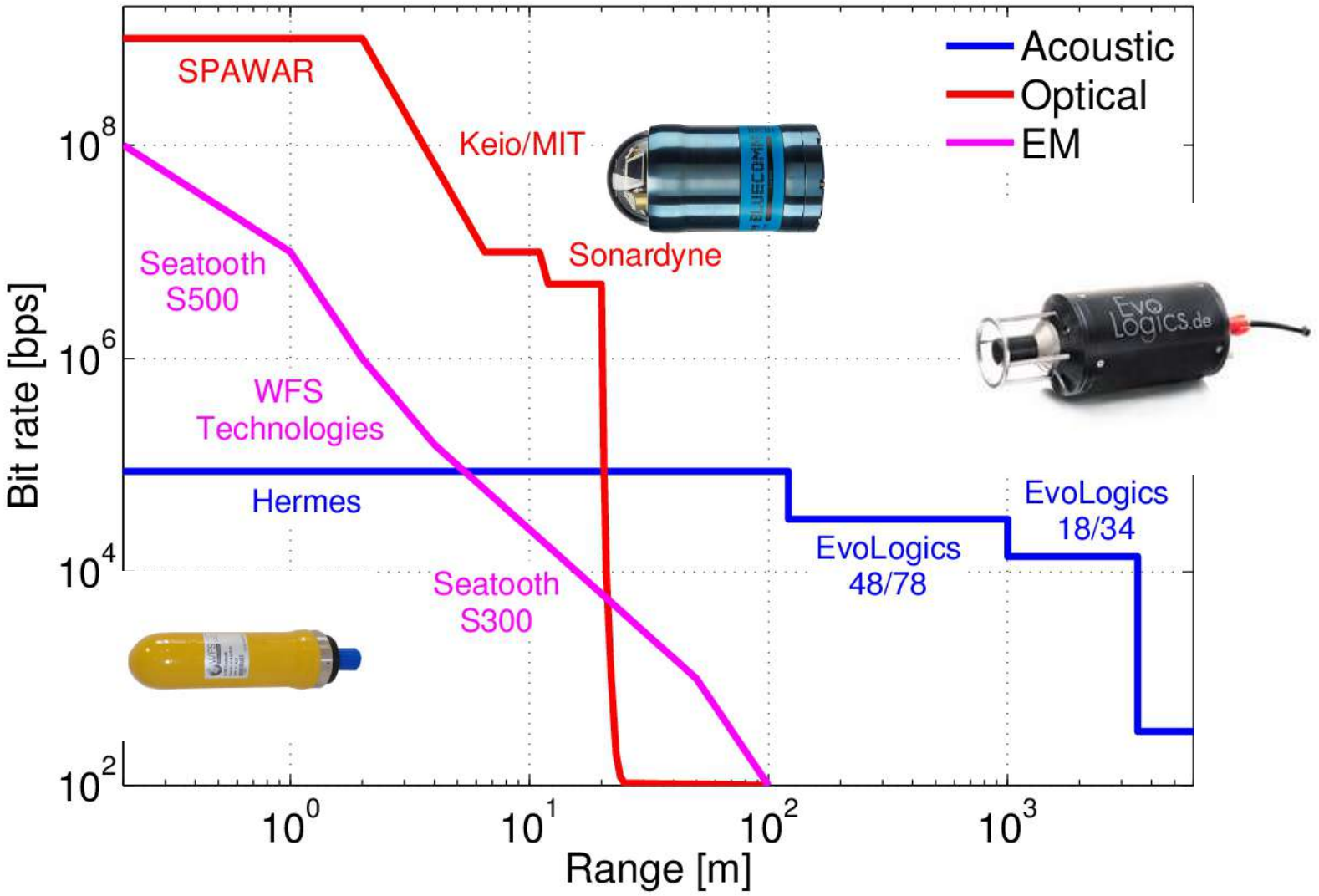
Light propagates for few meters under the sea



So… how to communicate?

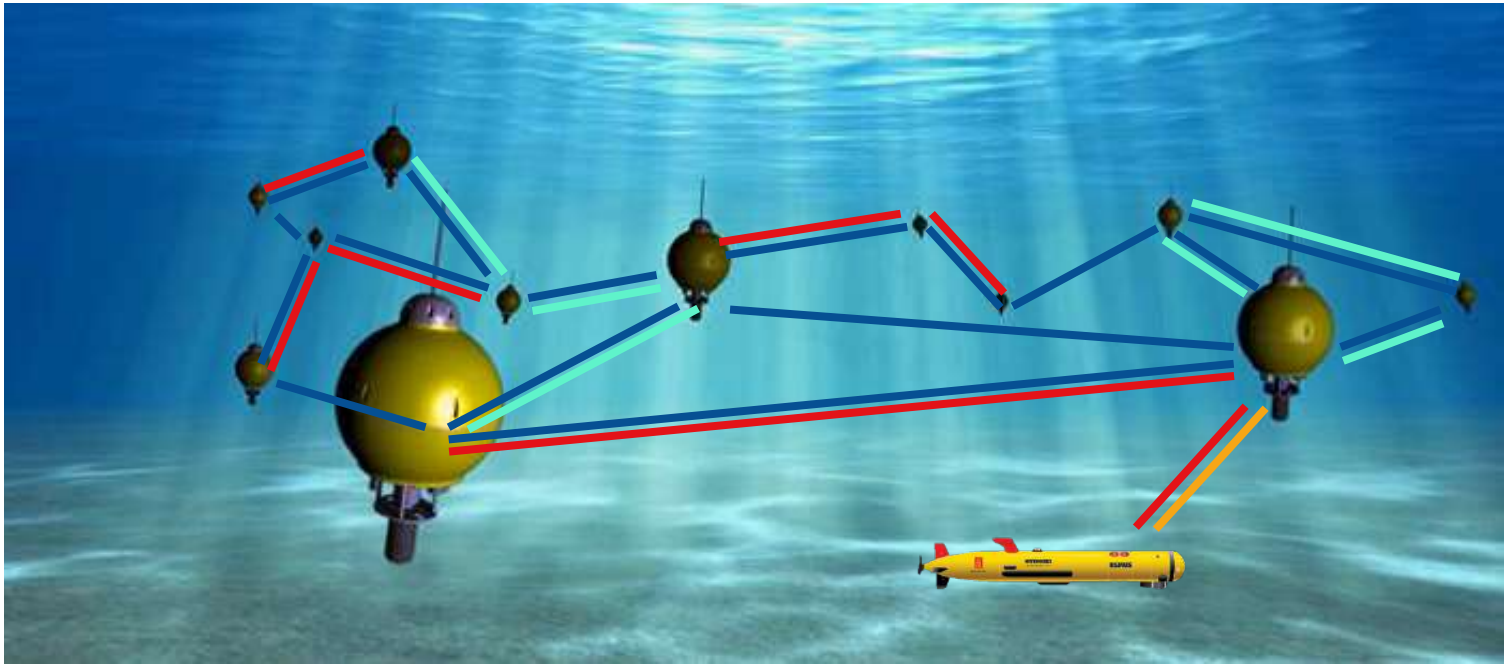
Marine mammals are able to communicate within each other through **sound** up to **several miles**

Communication Technologies

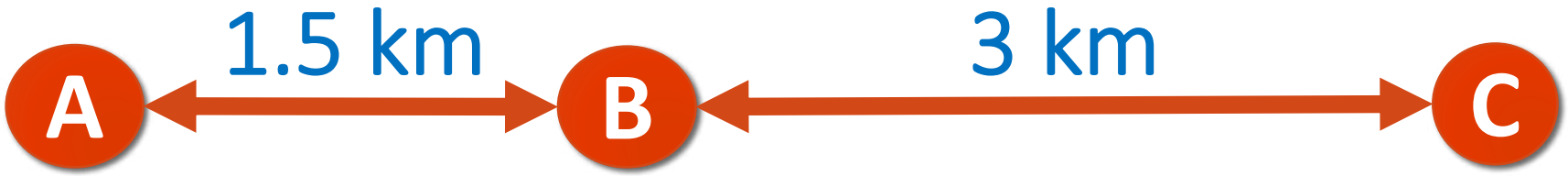


Multimodal networks

- Acoustics, low frequency
- Acoustics, mid frequency
- Acoustics, high frequency
- Optics



Acoustic communications



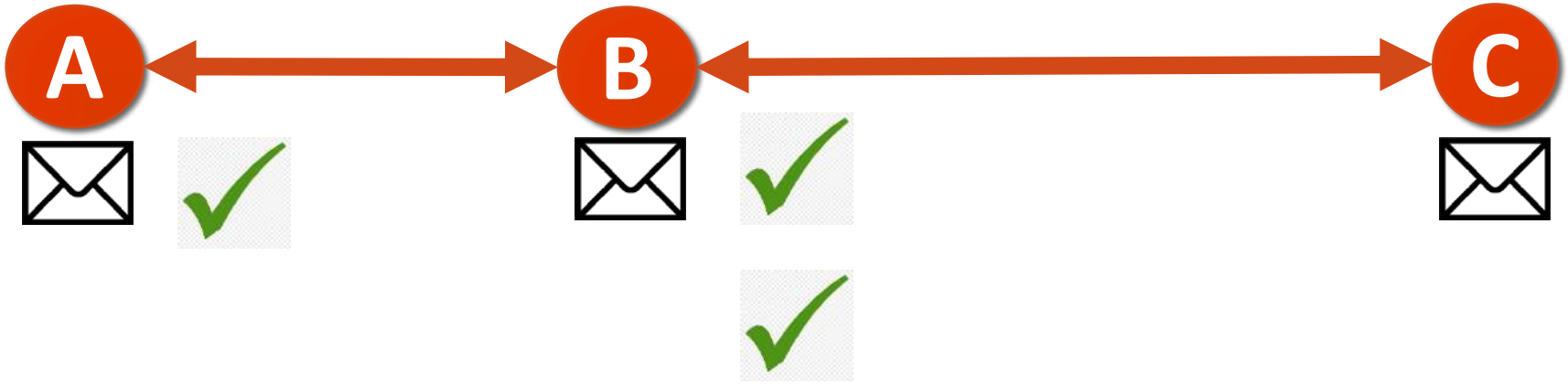
Speed of sound = 1500 m/s

Propagation delay **A→B = 1 s, B→C = 2 s**

Carrier sense MAC layers ineffective

TDMA requires 2 s time guard between slots

Acoustic communications



Propagation delay A→B = 1 s, B→C = 2 s

Packet duration = 0.5 s

Simultaneous transmissions without colliding!

Research activities

Analysis and design of network for:

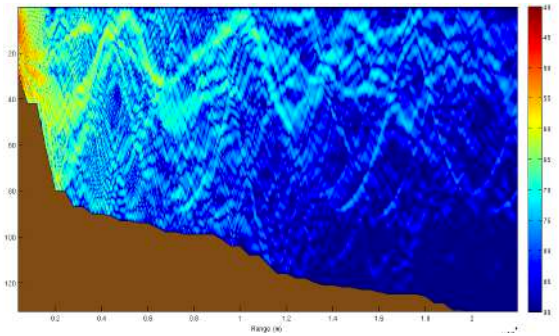
- data collection in dense and low-cost networks
- security in underwater networks
- control of underwater vehicle swarm

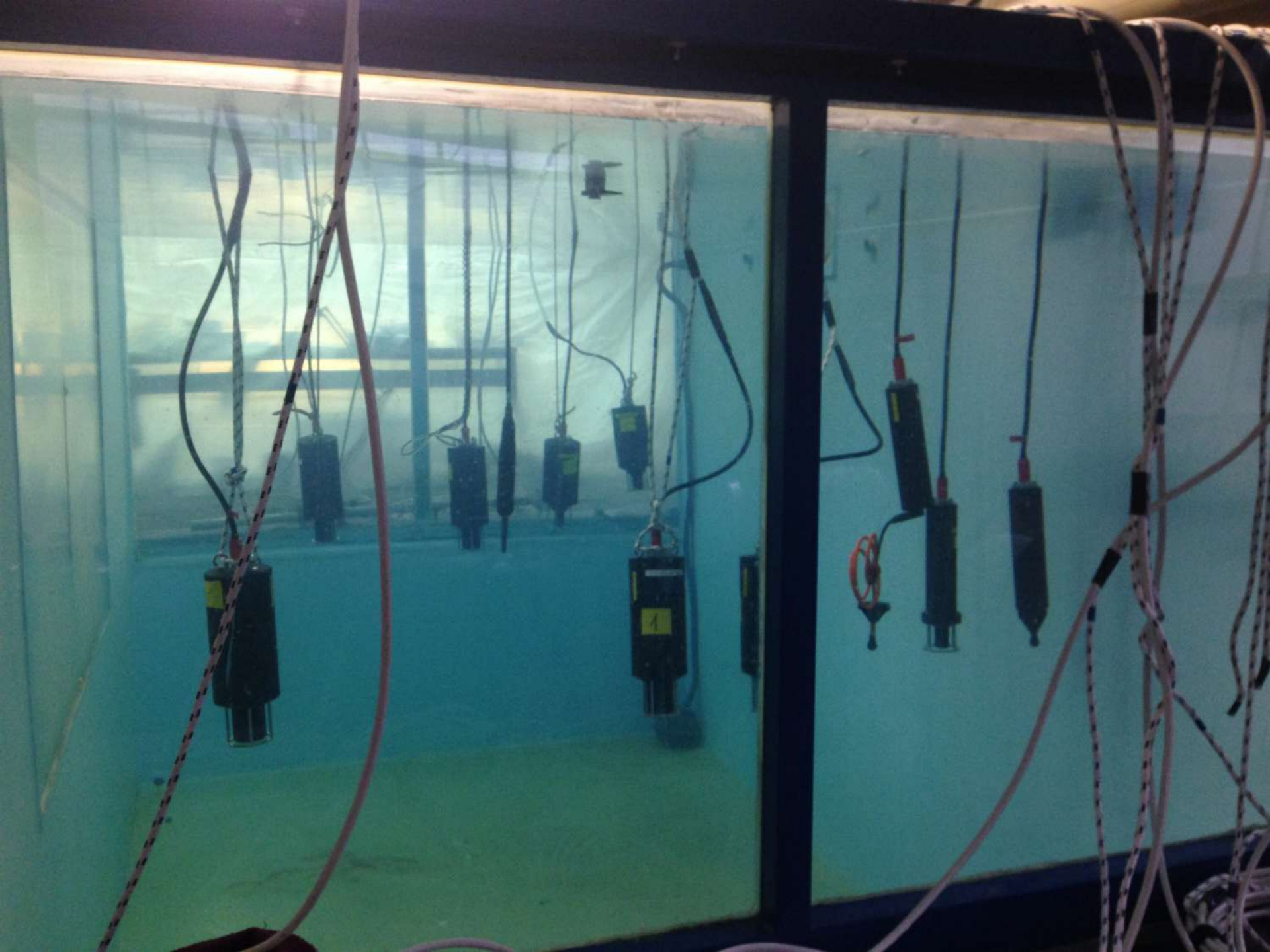
Performance evaluation

- DESERT Simulator
- WOSS (ray-tracer)

Not only simulations...

DESERT Underwater
University of Padova





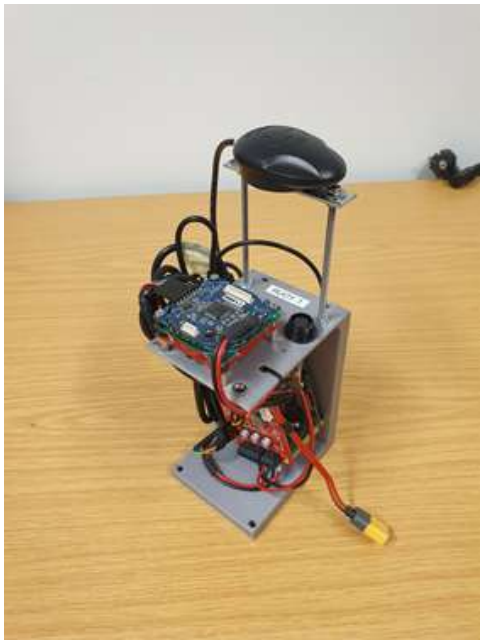
Real field experiments

We have ~~8~~ 7 modems

Sea-trial/lake experiments

- Same code for simulations and the real deployment

German Test 2020



German Test 2020

International Opportunities

Opportunities for your thesis abroad

We have several collaborations with international partners

Engage with them to:

- Discuss your research
- Use **testbeds and experimental** facilities remotely

Spend a period abroad for your master thesis and/or internship:

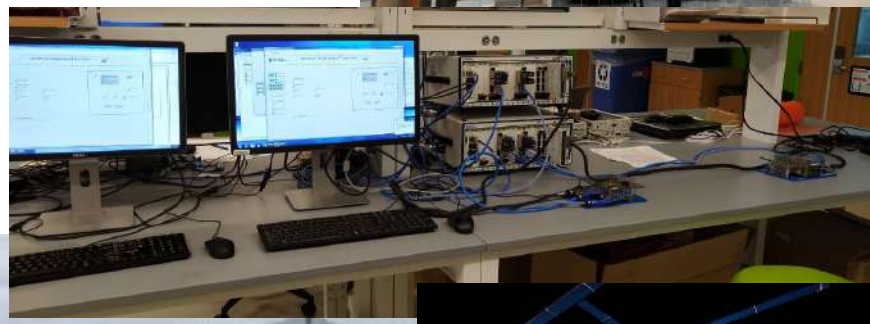
- in the last years, 3 students have spent 6 months in the U.S. for their theses at **NIST** (close to Washington, DC)
- New opportunity: **Northeastern University** in Boston

Topics:

- Machine learning in networks
- Cellular networks (5G, mmWaves, terahertz)
- Flying networks

Availability of experimental facilities based on software-defined **radios** and **drones**:

- Implement and test your thesis on real LTE and 5G radios
- Access to some of the world's largest research testbeds
- On-site or remote collaborations available

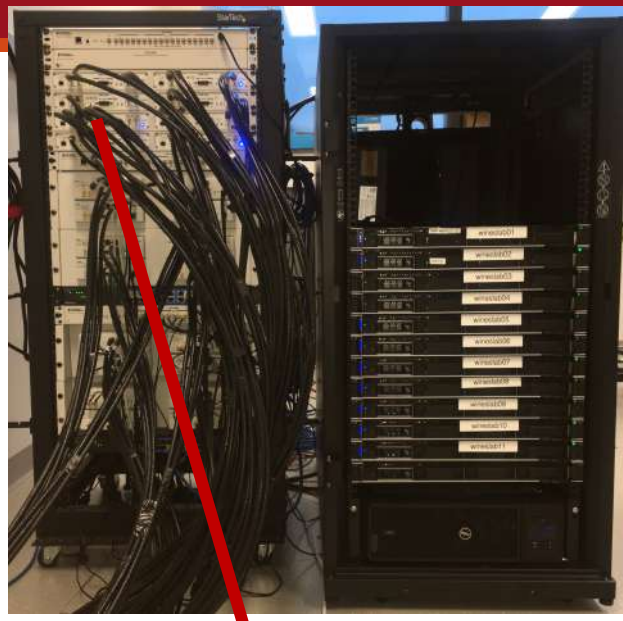


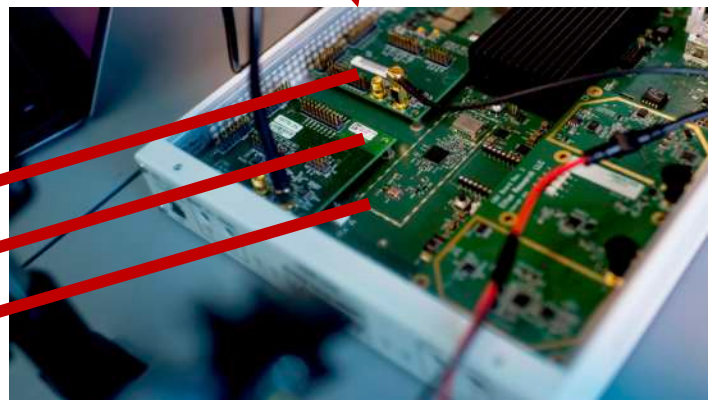
Close collaboration with UNIPD

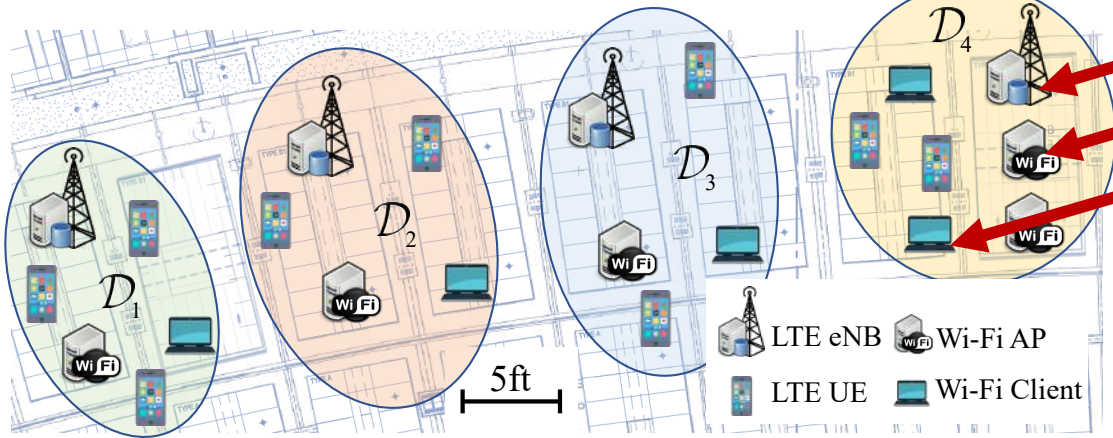
Michele Zorzi (zorzi@dei.unipd.it)

Example: ARENA

- 24 radios that control 64 antennas distributed across a building
- You can implement algorithms and communication techniques through **software** in each radio
- You can start from WiFi, LTE, or develop whatever you need
- MIMO and distributed beamforming studies
- For example, we studied how LTE, WiFi and video encoding services can share the same spectrum and computational resources







UNIVERSITÀ
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DI PADOVA

SIGNET

For a list of all project/thesis/collaboration activities that we propose, and if you have any question, visit

https://docs.google.com/document/d/1Fx0rM5SMt-iA9lx5ZXFasJ0PbrPSS-siptJ9PpSWCIs/edit?usp=sharing

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