



Centre for Research and Technology Hellas  
Information Technologies Institute



**CERTH**

CENTRE FOR  
RESEARCH & TECHNOLOGY  
HELLAS

# **CERTH-IT| Competences in AI-powered 5G/6G Networks**

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# Center for Research & Technology Hellas

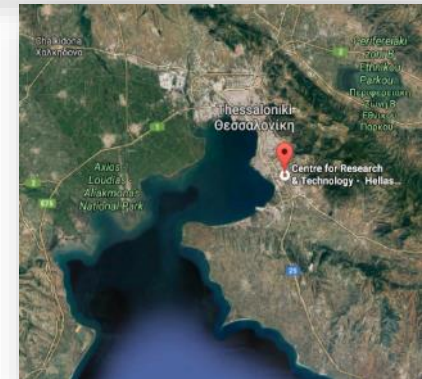
## CERTH

- **Founded in 2000** and is one of the leading R&D centers in Greece
- **Legal form:** Legal entity governed by private law under the auspices of the General Secretariat for Research & Innovation of the Ministry of Development & Investment
- **Personnel:**
  - >1500 employees
  - >2000 research projects
  - >2500 international partners
- **Annual Revenues > € 50M:**
  - 77% competitive research projects
  - 13% industrial research contracts
  - 10% government institutional funding
- **Numerous distinctions & awards**



**CERTH**  
CENTRE FOR  
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HELLAS

CERTH's revenues 10 x Annual government institutional funding!



Listed among **TOP-20 E.U. institutions** with the highest participation in competitive research grants

# Center for Research & Technology Hellas

## Information Technologies Institute (1/2)

- Founded in 1998 as a non-profit organisation.
- Part of CERTH since 2000.
- Leading Institution of Greece in the fields of Informatics, Telematics and Telecommunications
- Personnel (>700 employees):
  - ❑ **18 Senior Researchers, 60 Post docs, 80 MSc, 200 Assoc. Researchers**
- CERTH-ITI is currently involved in more than
  - ❑ **>70 Horizon Europe EC co-funded Research Projects**
  - ❑ **>220 Horizon2020 EC co-funded Research Projects**
  - ❑ **>80 Research/Innovate National R&D Projects**
- Around **20 M€ funding per year** during the last 4 years
- Publication record (last 5 years):
  - ❑ **>300 journals, 650 conferences, 100 books and book chapters, 6.500 citations**

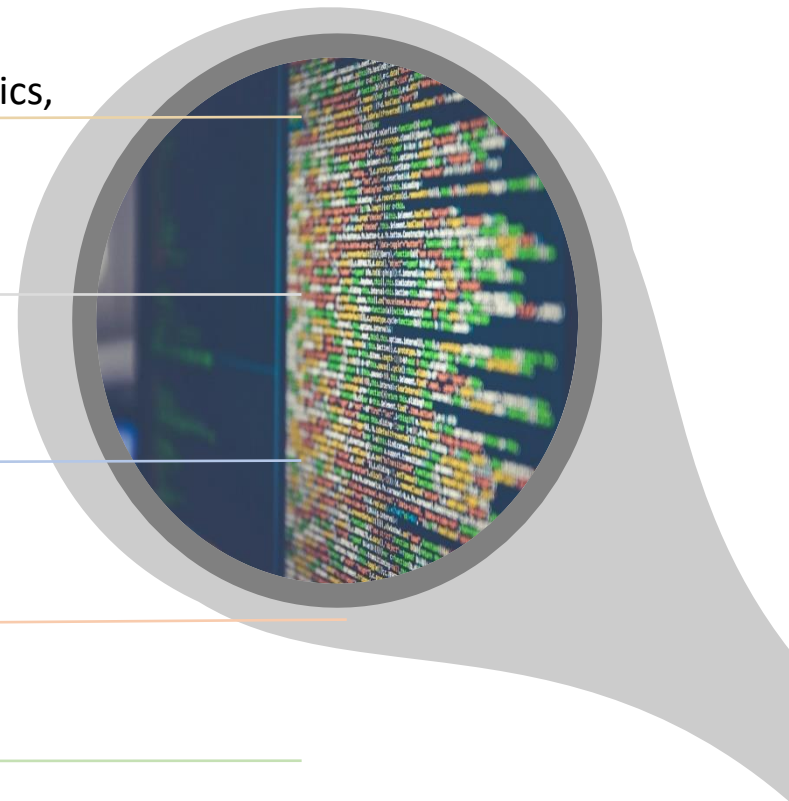


**1<sup>st</sup>** in Greece for **the last 7 consecutive years** in the participation in competitive research grants (FP7, H2020)

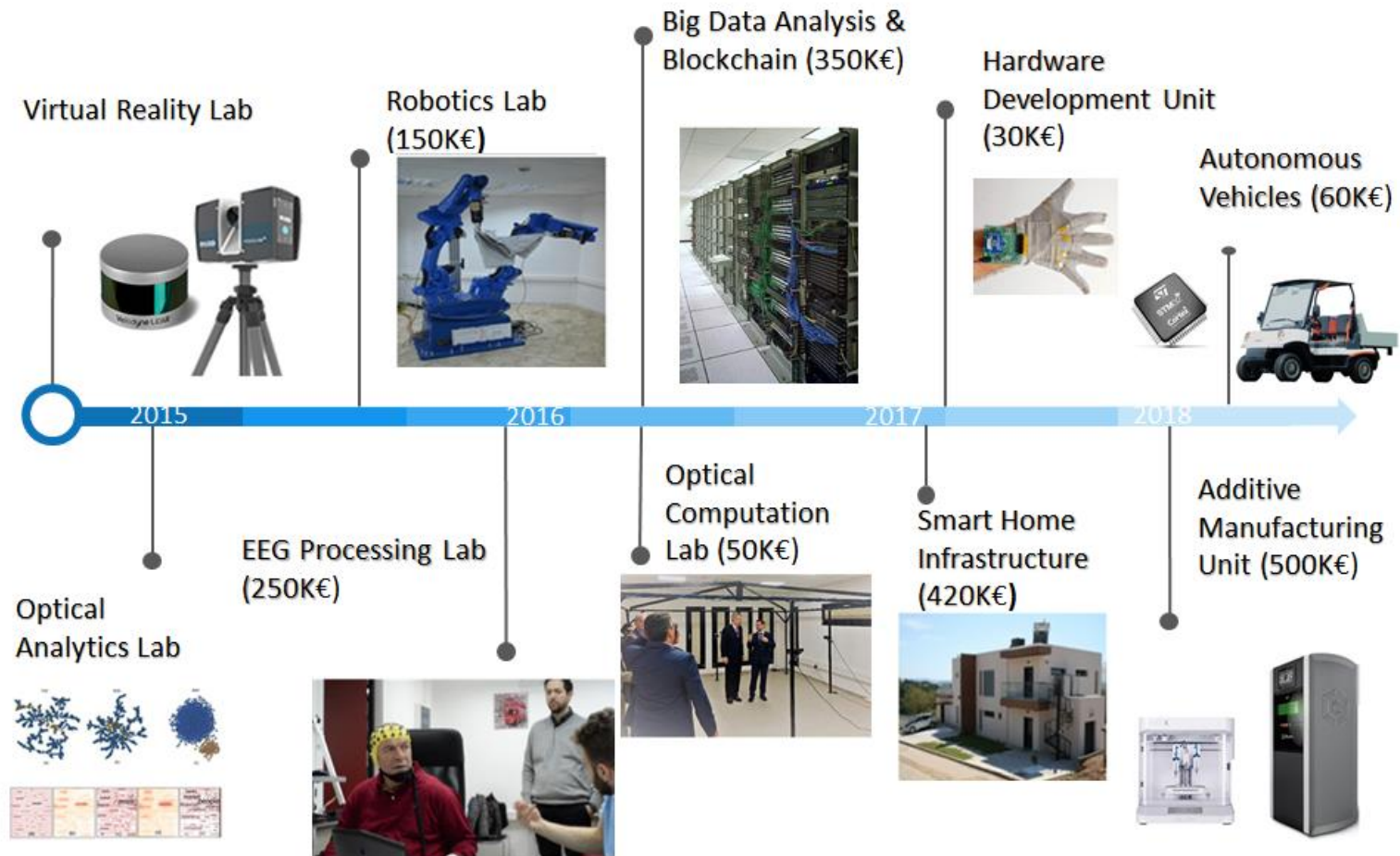
# Center for Research & Technology Hellas

## Information Technologies Institute (2/2)

- Artificial Intelligence, Machine Learning Prediction & Decision making
- Robotic Process Automation, Social Networks Analytics, Fighting Disinformation & Behavioural Analytics
- Visual Computing & Analytics, Virtual & Augmented Reality, Image & Video Processing
- IoT, Telecom (5G/6G), Smart Cities Cybersecurity, Energy & Sensor Networks, Blockchain
- e-Health & Robotics
- Remote Sensing & Environment



# Investing in R&D Infrastructures





# nZEB SmartHouse Digital Innovation Hub Infrastructure



▶ ITI nZEB SmartHouse - Digital Innovation Hub

- ❑ *9,57 kWp **Thin Film PVs** (Modbus enabled)*
- ❑ *5 kWh Lithium Ion **Batteries** (Modbus enabled)*
- ❑ *22kW **Charging Station** (OCPP enabled)*
- ❑ ***Smart Elevator** // 5kW recuperation*
- ❑ *Rain Water collection and redistribution as **Grey Water***
- ❑ ***Flexible Loads** // Full Monitoring and Control*
- ❑ ***Interoperability** (EnOcean, ZigBee, WiFi, Modbus, BACnet, LoRa, NB, Z-Wave, BLE, .... )*
- ❑ ***Islanded mode** supported*



▶ High Performance Computation Unit

- ❑ ***4 processing nodes***
  - *2 Intel Xeon 2.2GHz processors, 25MB cache memory each, 128GB RAM, 2 NVIDIA TESLA K40M graphic cards, 960 GB of SSD storage space, Red Hat Enterprise Linux for HPC*

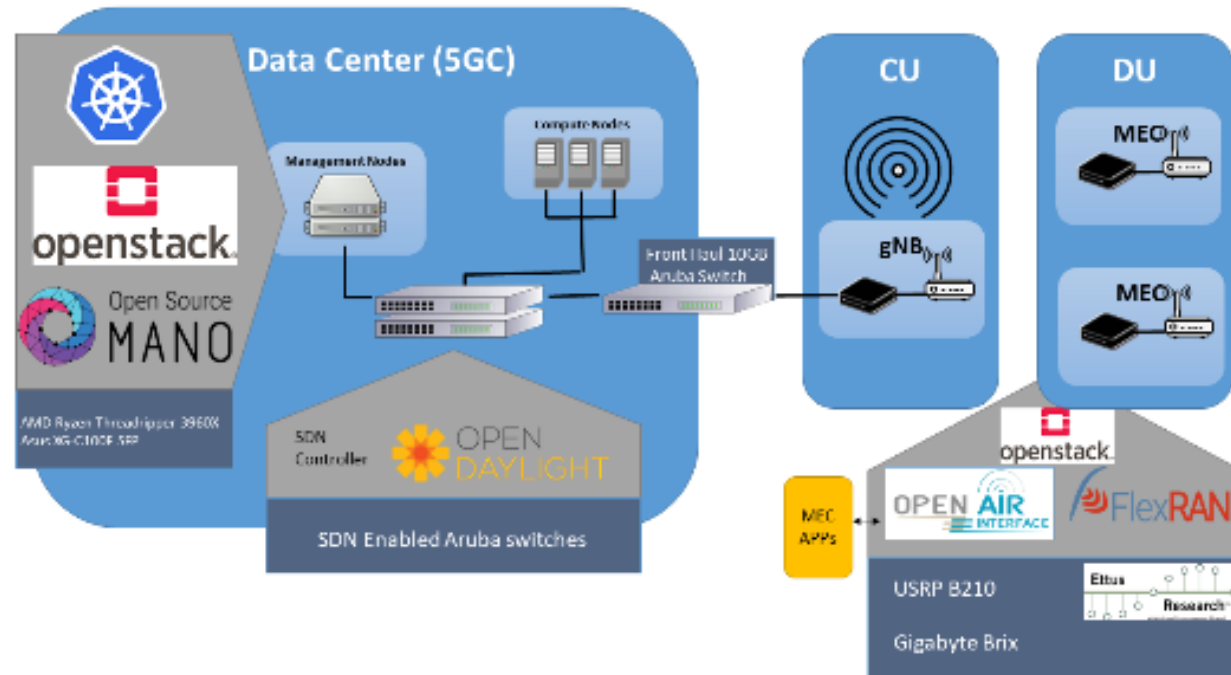
**5G Testbed  
(core & RAN)**



# CERTH-ITI 5G Testbed

## 5G Testbed:

A **5G Core Network**, a multi-access edge computing (MEC) cloud and fully **virtualized 5G RAN**, deployed along 8 nodes (2 VNF management/orchestration nodes, 3 computing nodes, 3 MEC nodes).



- **For VNF orchestration and management** OSM is utilized with an Openstack and Kubernetes deployment as virtualized infrastructure managers (VIM).
- **For the 5G components**, whitebox servers are used to implement all the CN and 5G RAN functionalities (5G gNBs deployed on Gigabyte BRIX connected to USRP B210s SDRs) utilizing the Open Air Interface (OAI) 5G software stack.

# CERTH-ITI Autonomous Vehicle

## Autonomous vehicle:

- CERTH operates an all-terrain vehicle (Polaris Ranger EV) with up to 70 km of autonomy, suitable for autonomous driving research.



## Vehicle Tele-operation Use case over 5G Testbed

- CERTH currently develops the software for autonomous driving, providing at the same time a **testbed for autonomous driving scenarios**.
- The vehicle involves a variety of sensors (cameras, LIDAR, GPS, IMU, laser scanners).

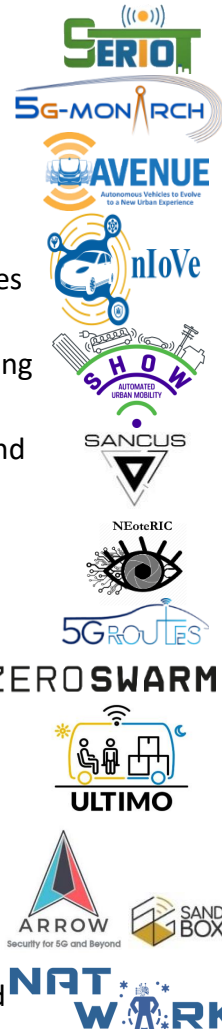




# 5G/6G Networking EC-funded Projects & Initiatives

## FP7... H2020 ... Horizon Europe

1. **SERIOT** - (Technical Partner) - (H2020-IOT-3-2017) - Secure and Safe Internet of Things - (IoT)
2. **5G-MoNArch** - (Technical Partner) - (H2020-ICT-2016-2017) - 5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond
3. **AVENUE** - (Technical Partner) - (H2020-ART-07-2017) - Autonomous Vehicles to Evolve to a New Urban Experience - (Physical Security & Cybersecurity for Autonomous Buses)
4. **nIoVe** - (**Coordinator**) - (H2020-SU-ICT-01-2018) - A novel Adaptive Cybersecurity Framework for the Internet-of-Vehicles - (Cybersecurity & Autonomous Buses)
5. **SHOW** - (**Technical Manager & Technical Partner**) - (H2020-DT-ART-2018-2019-2020) - SHared automation Operating models for Worldwide adoption - (RIS, Cybersecurity on Autonomous Buses)
6. **SANCUS** - (Technical Partner) - (H2020-SU-ICT-2019) - Analysis software scheme of uniform statistical sampling, audit and defence processes - (Cybersecurity on 5G networks)
7. **Neoteric** - (Technical Partner) - (H2020-ICT-2019-2) - NEuromorphic Reconfigurable Integrated photonic Circuits as artificial image processor - (AI-based Photonic Integrated circuits & Neuromorphic computing)
8. **5G-Routes** - (Technical Partner) - (H2020-ICT-2019-3) - 5th Generation connected and automated mobility cross-border EU trials - (V2X enablers & 5G)
9. **Zero-Swarm** - (**Coordinator**) - (HORIZON-CL4-2021-TWIN-TRANSITION-01-08) - Zero-enabling Smart Networked Control Framework For Agile Cyber Physical Production Systems Of Systems - (Cybersecurity on industrial 5G networks)
10. **ULTIMO** - (**Services Leader & Technical Partner**) - (HORIZON-CL5-2022-D6-01-01) - Advancing Sustainable User-centric Mobility with Automated Vehicles - (RIS, V2X, AI-based anti-jamming, physical security & cybersecurity on Automated Vehicles)
11. **ARROW** - (**Coordinator**) - (1st 6G-SANDBOX Open Call, HE-JU-SNS-2022-STREAM-C-01-01) - AI-powered Digital Security Processes over Cloud-native 5G and Beyond Networks - (Cybersecurity on 5G networks & Trials)
12. **NATWORK** - (**Coordinator**) - (HORIZON-JU-SNS-2023-STREAM-B-01-04) - Net-Zero self-adaptive activation of distributed self-resilient augmented services - (Cybersecurity & physical security on 5G/6G networks, RIS, AI-based anti-jamming)





# Cybersecurity

## Core Technologies & Expertise

### Privacy, Security & Cybersecurity

- Cyber-physical security & privacy
- Distributed AI-driven vulnerability identification & classification
- Blockchain & smart contracts
- AI-based Formal verification, Penetration testing & Hypothesis testing
- (Visual) Analytics Analytics Suite & SIEM technologies
- IoT and mobile (5G & beyond 5G) network security
- Early warning system & CTI sharing
- Security-by-design
- Cyber ranges & Honeypots
- Smart Grid security
- Biometrics, Surveillance, AVs & Drones



MONICA



AVENUE



NEMESYS



SDN-µSense



SMILE



FORTIKA



KONFID

Secure and Trusted Paradigm for Interoperable eHealth Services

ZERO SWARM



SPEAR



Member & active contributor of



# 5G-tailored AI-based Intrusion Detection System

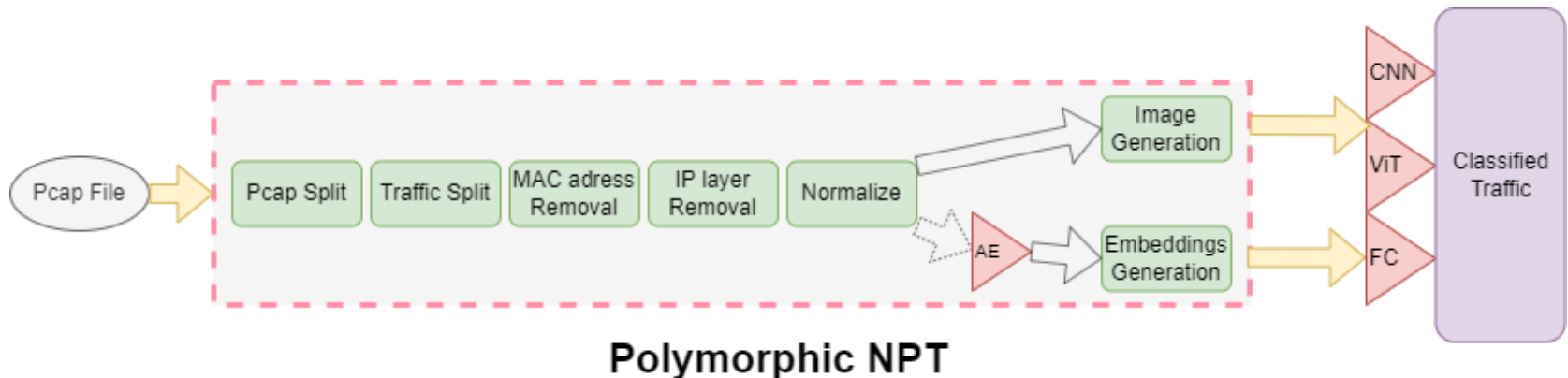
## ❖ Polymorphic NPT

- .pcap data **preprocess** toolkit
- Raw payload is **transformed** into **images** or meaningful representations (**embeddings**)
- **Images** are classified using **Vision Transformer**
- **Embeddings** are **generated** with autoencoders and **classified** with fully connected networks



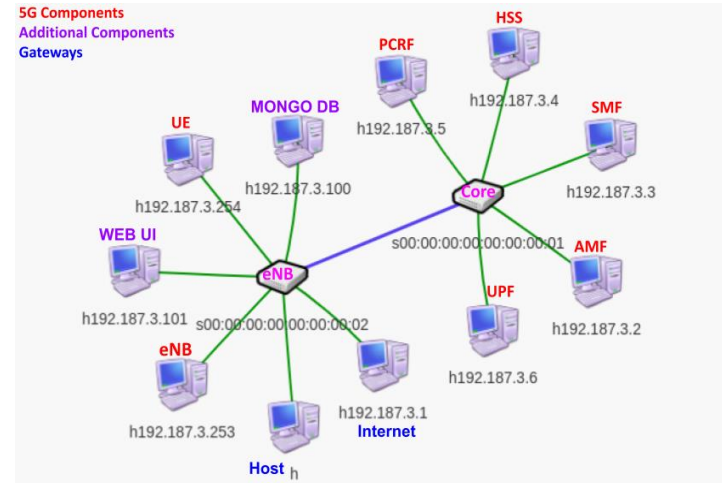
Expansion of the Polymorphic NPT's embedding generation method to compensate the lack of labeled data

- Utilize **NLP** based techniques to derive .pcap embeddings (**packetToVec**)
- Generate embedding via BERT models (**MalBERT**)
- Make use of **memory** in looking for patterns by replacing regular autoencoders with **LSTM** autoencoders



# 5G-tailored Attack Generation

- Implementation of an **SDN-based 5G core network environment**
- Experimentation of **cyber-attack and digital security processes**
- Generation of **normal and malicious traffic (various attacks on 5G protocols) in order to produce datasets** that can be used by the detection mechanisms



- **Attack on the AMF component** that exists in the 5G core network using the **SCTP protocol**
- Took advantage of the capabilities provided by the SCTP, as well as used against the AMF component that the same SCTP uses to protect the AMF.

As long as the AMF receives an attack on the SCTP, it also rejects the packets from other components. In this case, the connection between the AMF and the HSS is interrupted by the attack

No.	Time	Source	Destination	Protocol	Length	Info
15770	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15771	0.000000000	192.187.3.4	192.187.3.2	TCP	76	7 (TCP out-of-order) [TCP numbers reset]
15772	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15773	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15774	0.000000000	192.187.3.2	192.187.3.4	TCP	76	7 (TCP out-of-order) [TCP numbers reset]
15775	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15776	0.000000000	192.187.3.2	192.187.3.4	TCP	76	7 (TCP out-of-order) [TCP numbers reset]
15777	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15778	0.000000000	192.187.3.2	192.187.3.4	TCP	76	7 (TCP out-of-order) [TCP numbers reset]
15779	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15780	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
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15782	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15783	0.000000000	192.187.3.2	192.187.3.4	TCP	76	7 (TCP out-of-order) [TCP numbers reset]
15784	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
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15787	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15788	0.000000000	192.187.3.2	192.187.3.4	TCP	76	7 (TCP out-of-order) [TCP numbers reset]
15789	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0
15790	0.000000000	192.187.3.2	192.187.3.4	TCP	56	3088 → 3034 [EST. ACK] Seq=14524 Win=0 Len=0

Task [run PCRF simulation process] \*\*\*\*\*  
 Pausing for 15 seconds  
 Task [run AMF simulation process] \*\*\*\*\*  
 Pausing for 15 seconds  
 Task [run UE simulation process] \*\*\*\*\*  
 Pausing for 15 seconds

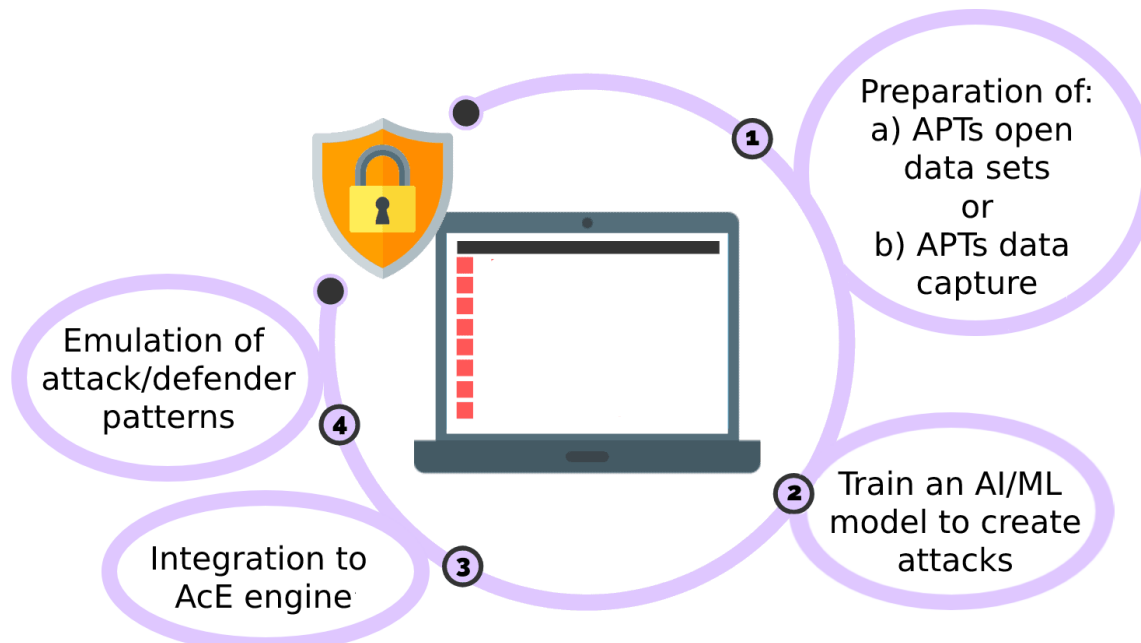
# AI-based Penetration Testing in 5G

## Custom Architecture Advantages

1. **No need for feature extraction and domain expertise**
2. **Adaptability** to future and 5G-specific attacks
3. **Extraction of most representative features** in the latent space through **transformer embeddings**
4. **Pipelined with a generative model for PCAP file creation**

## Envisioned functionality

- Efficient **adaptation of embeddings to 5G-specific attacks**
- Enhanced **augmentation capabilities** regarding attack scenarios





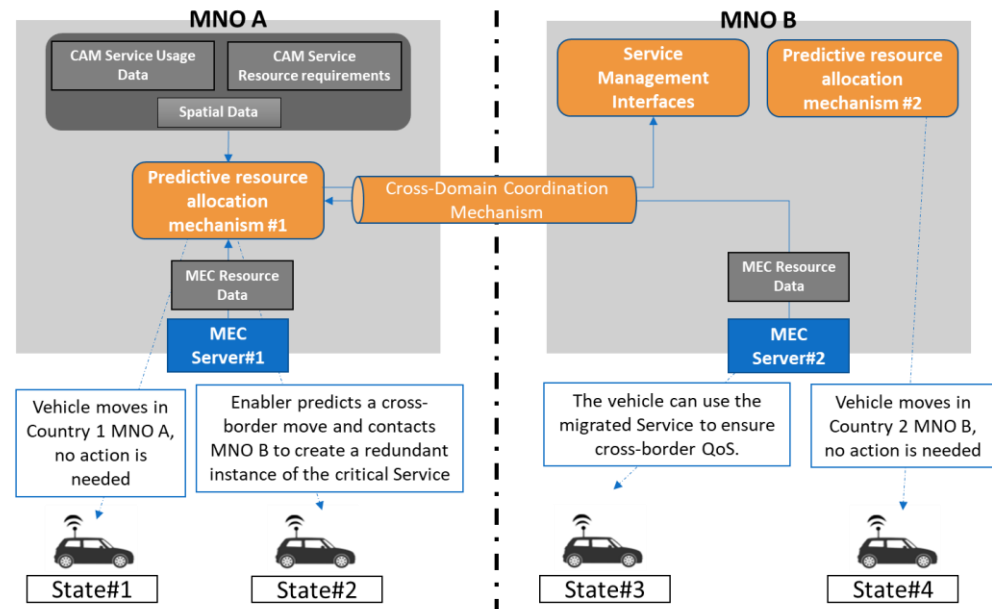
## Predictive **resource allocation** of V2X related network functions using AI algorithms

### Problem

- Automotive services have **stringent requirements** related to low latency and reliability.
- These can be met using edge resources i.e. by deploying components of the E2E services as close as possible to the network edges. However, edge resources are finite.

### Solution

- The proposed mechanism uses two SotA AI mechanisms, to:
  - initially **predict future vehicle location** and then
  - support the optimal positioning of the VNFs** related to V2X services in the available MEC servers.
- In the context of the existing project it **predicts the need for cross-border VNF placement** to ensure **service continuity** and **satisfy stringent resource requirements** by pre-emptively requesting resources.



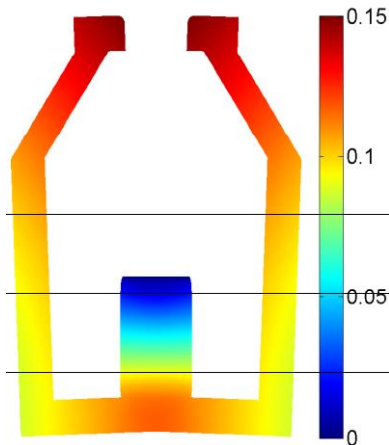
# Multiphysics Simulations

- Design and analysis of **Micro-Electro-Mechanical Systems (MEMS)** using FEM

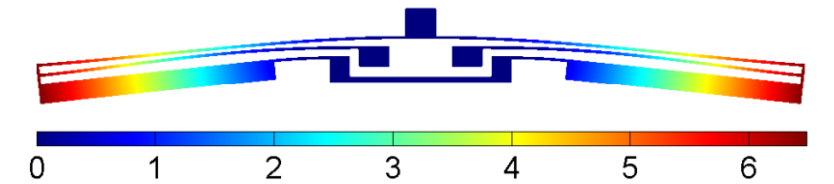
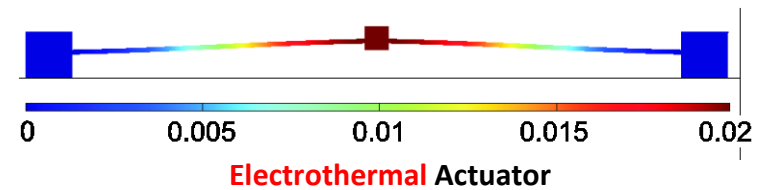
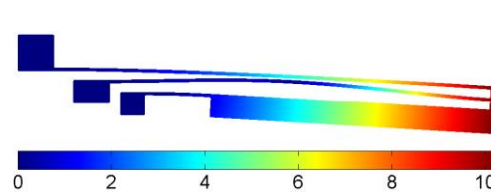
## Static FEA with objectives of:

- Maximum displacement
- Stress concentration
- Temperature minimization
- Topology optimization

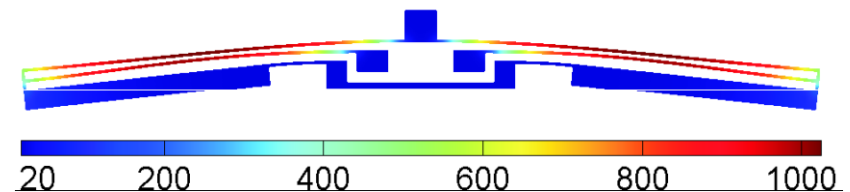
**Piezoelectric  
Microgripper**



**Two-Hot-Arm  
Electrothermal Actuator**



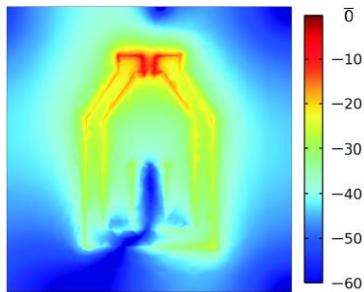
**Displacement Analysis  
(Double Two-Hot-Arm Electrothermal Actuator)**



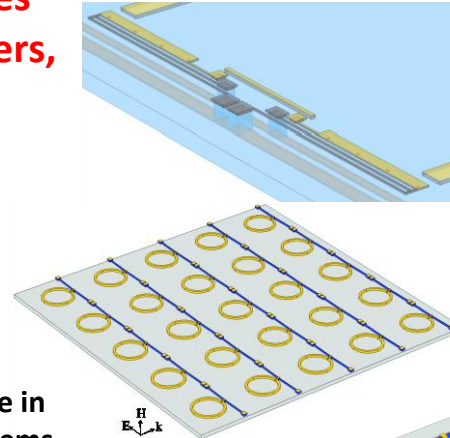
**Thermal Analysis  
(Double Two-Hot-Arm Electrothermal Actuator)**

# Computational Electromagnetics

- Reconfigurable RF-MEMS Enabled **Metasurfaces**
- Design and simulation of **antennas, filters, wireless power** components

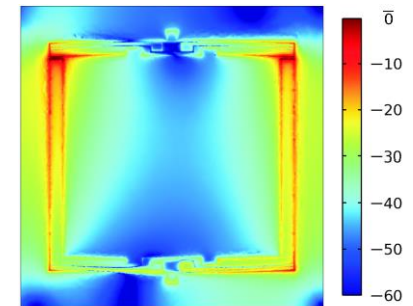


Electric Field on **Microgripper Split Ring Resonator (SRR)**

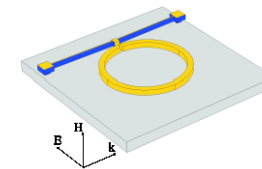
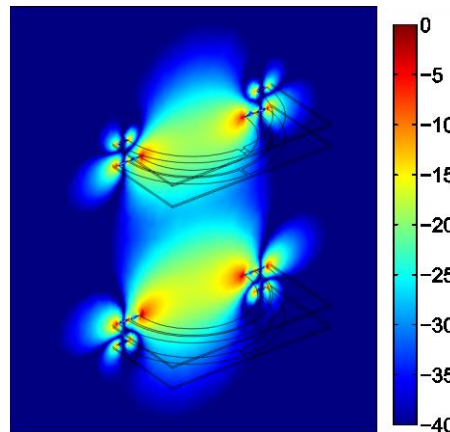
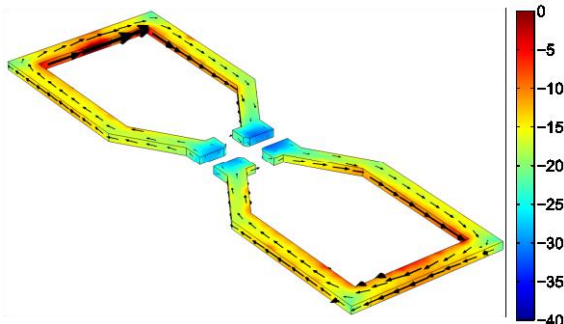


Magnetic Resonance in **Wireless Power Systems**

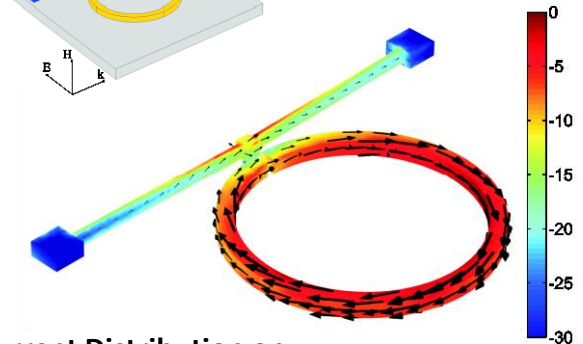
Electric Field on **Double Two-Hot-Arm SRR**



Current Distribution on **Microgripper based Metasurface Unitcell**



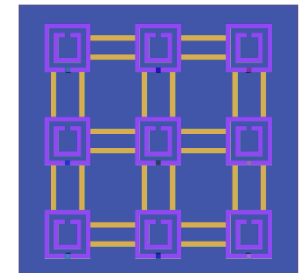
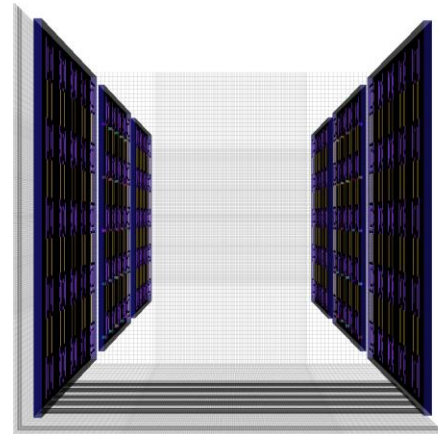
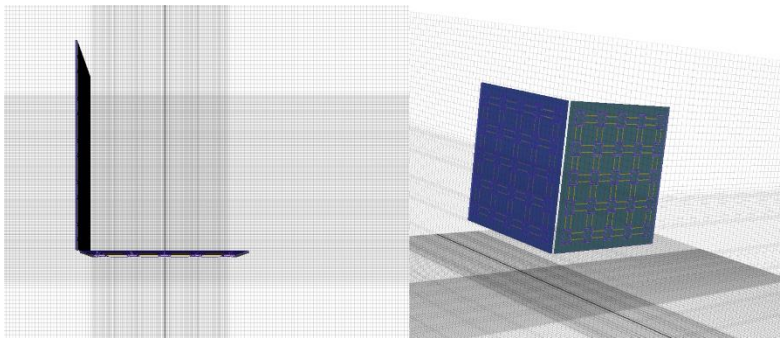
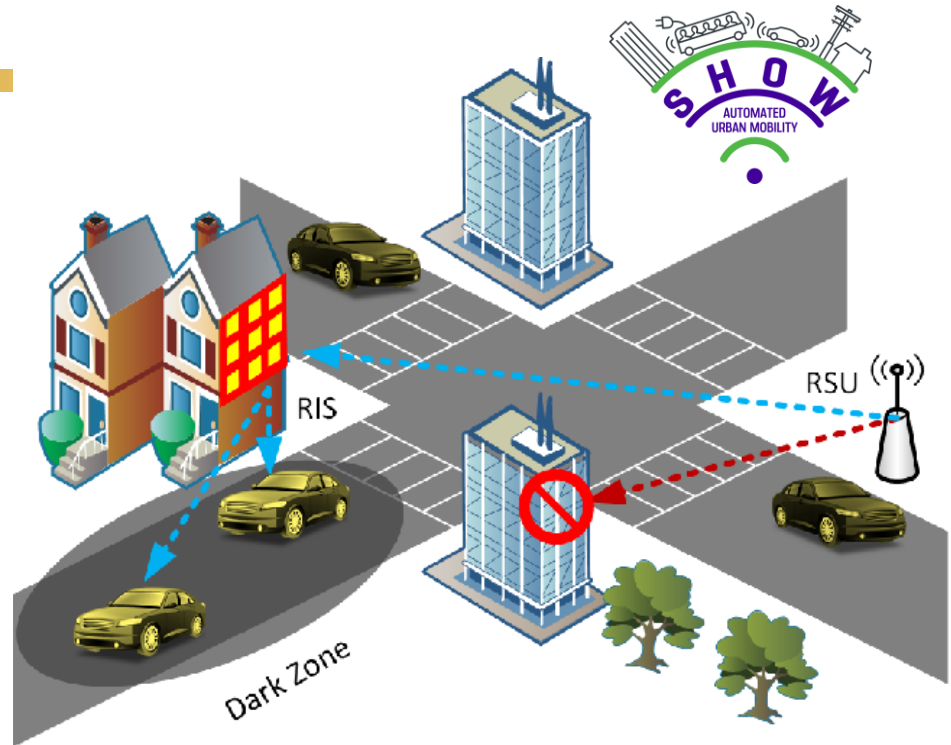
Current Distribution on **Electrothermal based Omega SRR**



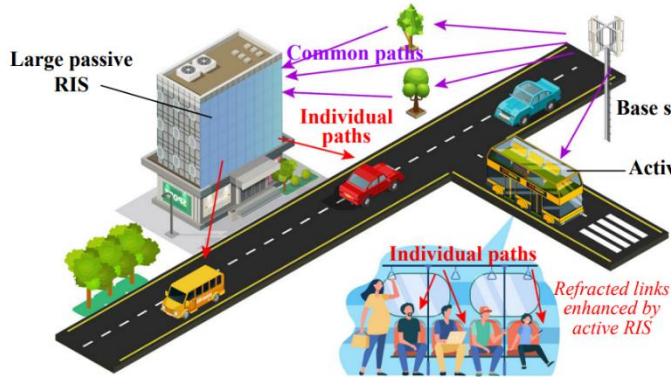
# Reconfigurable Intelligent Surfaces

Uses cases of RIS in V2X:

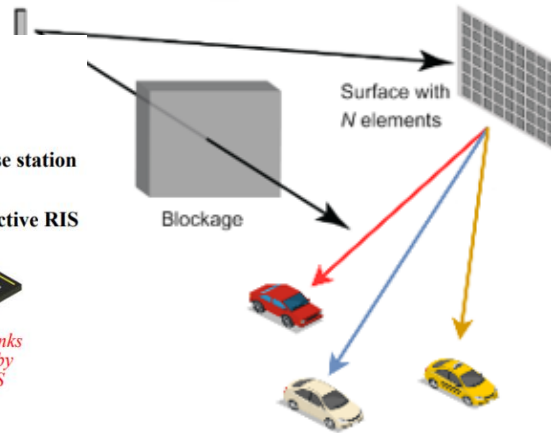
- ▶ **Recovery of Non-Line-of-Sight** connection between the transmitter and the receiver.
- ▶ **Optimization of the QoS** of the users.
- ▶ **Minimization of the cross-reference among the multiple antennas.**
- ▶ **Minimization of the latency.**
- ▶ **Maximization of data rate.**
- ▶ **EMC Shielding / Transparent Antennas**
- ▶ **Energy Harvesting / Wireless Power**



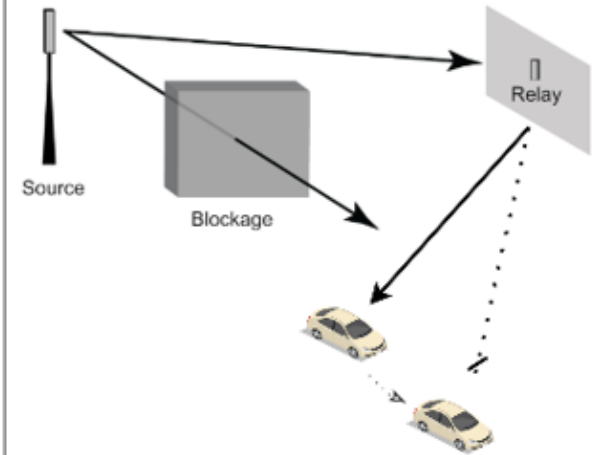
# Reconfigurable Intelligent Surfaces



Using RIS



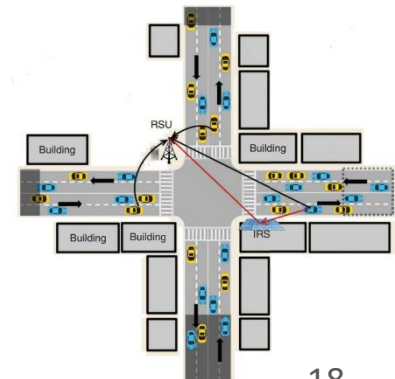
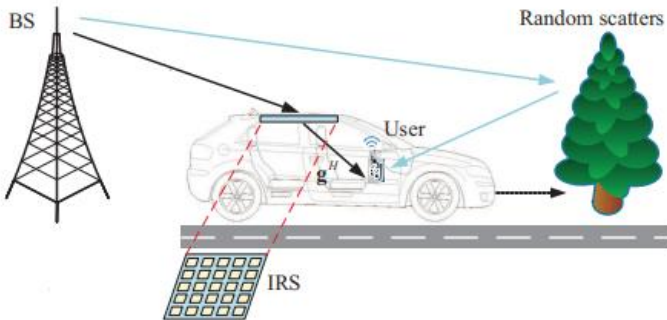
Using Relays



- ❑ AI-based **Anti-jamming & Anti-spoofing** (**RIS in V2X**)

- ❑ RIS unit can both send and receive a signal **at the same time**.
- ❑ RIS supports beamforming in numerous directions.

- ❑ Relays **either** transmits **or** receives signals.
- ❑ Relay supports **only in one**.





# CERTH-ITI in DeepSense 6G Challenge



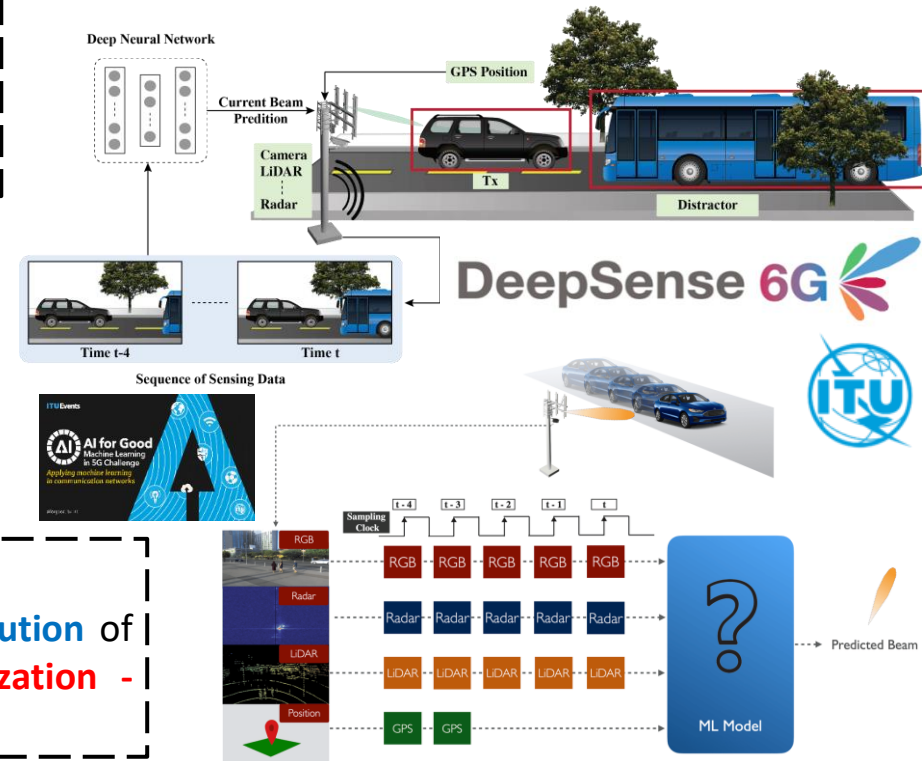
**Challenge Objective:** Given a **multi-modal training dataset** consisting of data collected (**RGB cameras, LiDARs, Radars, GPS receivers**) at different locations with diverse environmental features, develop **machine learning-based models** that can **adapt** to and **perform** accurate **sensing-aided beam prediction** at an entirely **new location**.

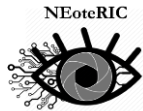
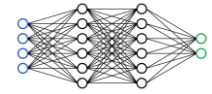
- **Beam Classification**
  - Predict the optimal beam index at time  $t$
- **Blockage Classification -- extension**
  - Blockage prediction using wireless signatures

**Ranking: 5<sup>th</sup> Place for ULTIMO Team (Top 5)**

For a new late fusion model for the **simultaneous solution** of the double problem of **Beam Classification-categorization - Blockage Classification -- extension**

**ML5G-PS-011: Multi Modal Beam Prediction**  
**Challenge 2022: Towards Generalization**  
**International Telecommunication Union (ITU)**



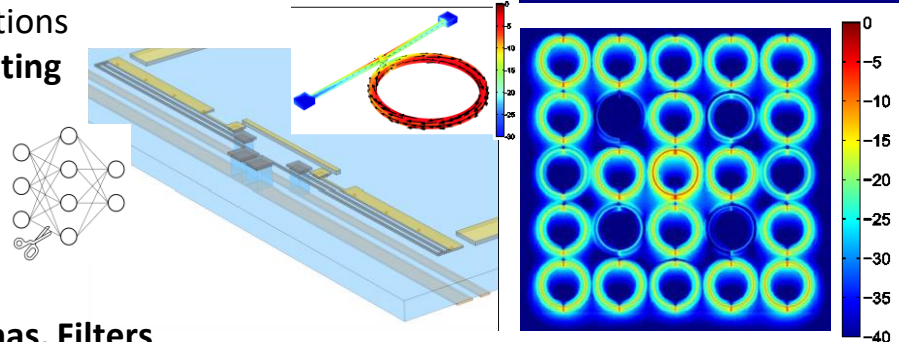
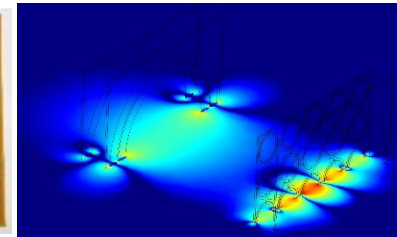
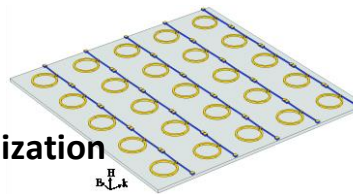
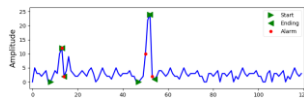


### Technology areas

- **IoT and THz communication technologies, 5G/6G networks**, sensing/navigation technologies, cloud/edge and computing technologies, distributed ledger technologies (blockchain), (semantic) interoperability
- **data and visual analytics, multiphysics simulation**, data mining, **machine and deep learning**, federated and swarm learning, explainable AI, **neuromorphic computing**, virtual and augmented reality, image processing, computer and cognitive vision, human computer interaction, **data anonymization & curation**
- system integration, mobile and web applications, hardware design and development, **smart materials (metasurfaces)**, **wireless power transfer** technologies, **photonics**, smart grid technologies and solutions, social media analysis.

### SNS Domain:

- **AI-powered Cybersecurity** in 5G/6G networks
- **Cloud/Edge computing** with AI and **data anonymization**
- **State synchronization** for data-centers/cloud/5G
- **AI Predictive resource allocation** of V2X network functions
- AI application in **Physical Layer/Neuromorphic computing**
- AI application in **Photonic Integrated circuits (PICs)**
- **Reconfigurable Intelligent Surfaces (RIS)**
- AI-powered **Anti-jamming** (RIS in V2X)
- Design and **multiphysics simulation** of metasurfaces
- **Simulation tools** (FDTD, FEM, Ray tracing)
- Metamaterial-based **Wireless Power Transfer, Antennas, Filters**
- **5G Testbed (core & RAN) & several verticals** (industry, health, autonomous vehicles)
- **Smart home infrastructure & EMF exposure prediction**





### HORIZON-JU-SNS-2024-STREAM-B (RIA)

- **01-01: System Architecture**
  - New design approaches for 6G system architecture systems
  - Native and trustworthy **integration of AI for telecommunications**
  - Mechanisms, leading to partial or complete **Digital network twinning**, applied in 6G
  - New Data Transfer Paradigms
- **01-02: Wireless Communication Technologies and Signal Processing**
  - Novel techniques for **integrated sensing and communication**
  - **Machine learning empowered** physical layer evolutions
  - Cell-free and extreme exploitation of MIMO technologies potentially including **reconfigurable surfaces**
  - Seamless integration of multiple frequency bands (**EMF issues**)
- **01-03: Communication Infrastructure Technologies and Devices**
  - Ultra-high energy efficiency especially in optical networks (**AI/ML approaches**)
  - 3D networking for 6G networks (**SDN, resource allocation, security aspects**)
  - Unified NTN service provision
  - Integration of Optical and Wireless Technologies
- **01-04: Reliable Services and Smart Security**
  - Exploitation of (distributed) **trusted AI/ML for 6G infrastructures**
  - Cooperative holistic **E2E security and privacy solutions** for 6G architectures
  - Smart and **trustworthy service frameworks**
  - Zero-touch integrated **security deployment**
  - Integration of secured 6G communications via **Quantum key distribution and post-quantum cryptography** support

### HORIZON-JU-SNS-2024-STREAM-B (RIA)

- **01-05: International Collaboration – EU-JP**
  - AI-enabled radio access network (RAN) solutions including physical layer and signal processing technologies for 6G RAN such as distributed MIMO and user centric network, **RIS implementations and AI-enabled integrated RAN/Core network functions**
  - Improvement and **expansion of data sets**, tools and algorithms for efficient **new AI/ML solutions**
- **01-06: International Collaboration – EU-KOR**
  - **Machine learning-based** channel estimation, channel state information transmission, channel decoding, distributed MIMO and beam management.
  - Mobility management, **wireless resource management**, automated maintenance, and self-optimization of network parameters
  - Improvement and **expansion of data sets**, tools and algorithms for efficient **new AI/ML solutions**
- **01-07: Sustainability Lighthouse**
  - Improving **energy efficiency** and total **energy consumption**. It includes network and device side, e.g. enabling more energy efficient network operations covering **power usage monitoring**, multi-criteria optimisation, self-diagnose & healing. **Minimization of EMF effects**
  - Developing strategies to **ensure that AI/ML technique** to be used in future 6G networks **are environmentally sustainable**



- **01-08: Reliable AI for Reliable Communications Systems and Services**
  - Methodologies for **centralized, distributed and federated applications**, reference use cases, **data acquisition and generation, repositories, curated training and evaluation data**
  - AI environment (training, development, production) evaluation, **Vulnerability assessment of AI models** for different telecommunication applications, **Reliable and trustable AI life cycle**
  - **Robust and trustworthy AI/ML** validating the “**quality**” **datasets** from different scenarios, which influences the outcomes of the AI systems, as well as the corresponding outcome of AI.
  - Verification and validation of **AI techniques over experimental platforms**, additionally providing the associated datasets

### HORIZON-JU-SNS-2024-STREAM-C (RIA)

- 01-01: SNS Microelectronics Lighthouse 10.0
  - **Neuromorphic and photonic computing**
  - Availability of **large-scale data sets and training sequences** as part of open repositories.

### HORIZON-JU-SNS-2024-STREAM-D (IA, with FSTP)

- 01-01: SNS Large Scale Trials and Pilots (LST&Ps) with Verticals (IA) 25.0
  - **CCAM, Health, and Energy verticals**
  - Optimize energy consumption, **EMF exposure**, trustworthiness, privacy

### HORIZON-JU-SNS-2024-STREAM-CSA (CSA)

- 01-01: SNS Operations and Output optimisation 4.0
  - **Dissemination and standardization activities**

### HORIZON-ER-JU-2024-FA2-SNS

- EU-RAIL – SNS SYNERGY: Digital & Automated testing and operational validation of the next EU rail communication system





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# Open for Collaboration!



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**HYPERLEDGER**



**INTERNATIONAL DATA  
SPACES ASSOCIATION**





# International Cooperations (Indicative List)

## UNIVERSITIES / RESEARCH CENTERS



## INDUSTRY / SMES

