Centre for Research and Technology Hellas
Information Technologies Institute

CERTH
CENTRE FOR
RESEARCH & TECHNOLOGY
HELLAS

CERTH-ITI 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

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- **Annual Revenues > € 50M**:
  - 77% competitive research projects
  - 13% industrial research contracts
  - 10% government institutional funding

CERTH's revenues 10 x Annual government institutional funding!

- **Numerous distinctions & awards**

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**

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

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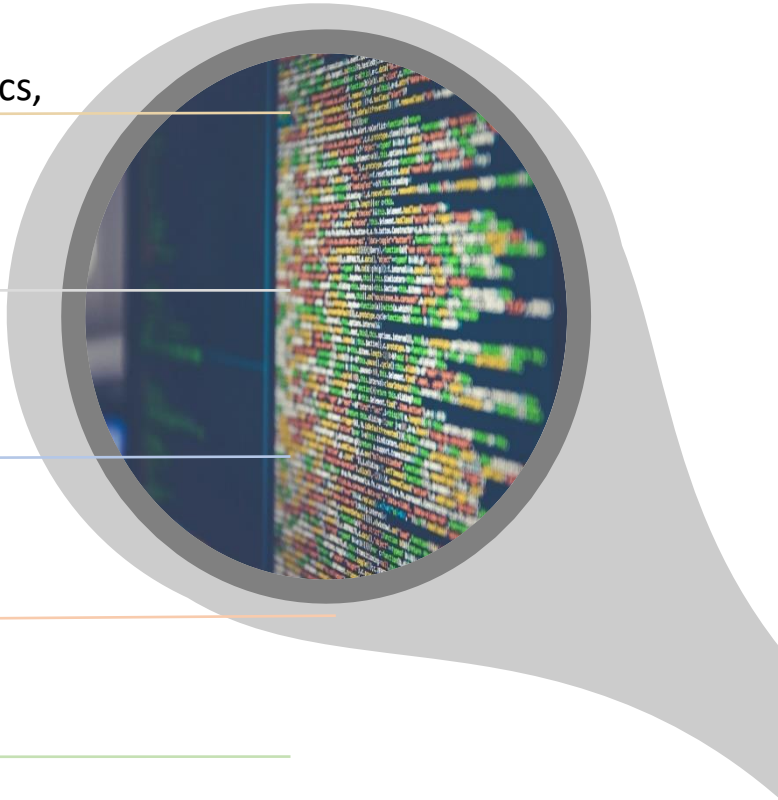
Information Technologies Institute (2/2)

- 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



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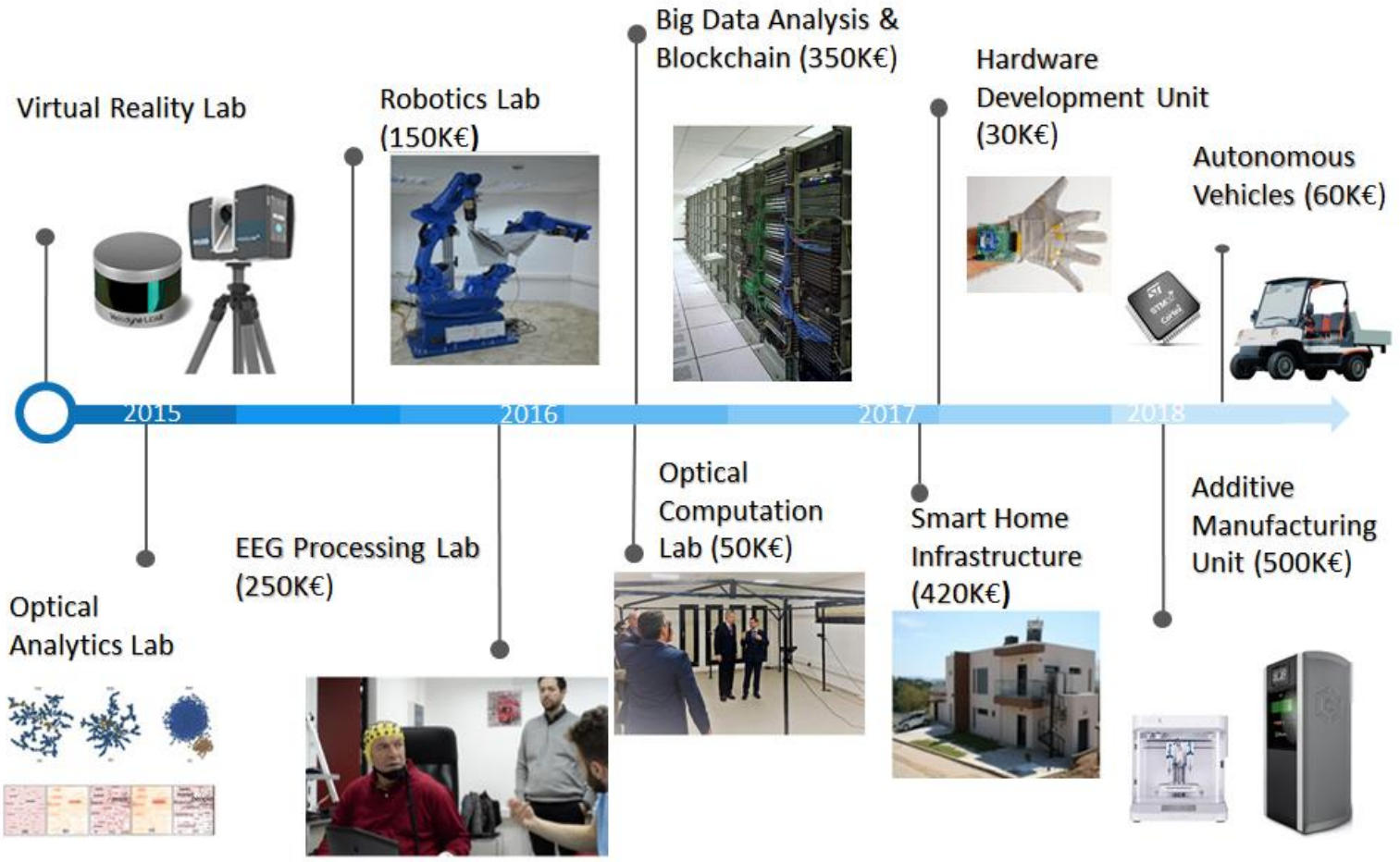
Investing in R&D Infrastructures



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nZEB SmartHouse Digital Innovation Hub Infrastructure

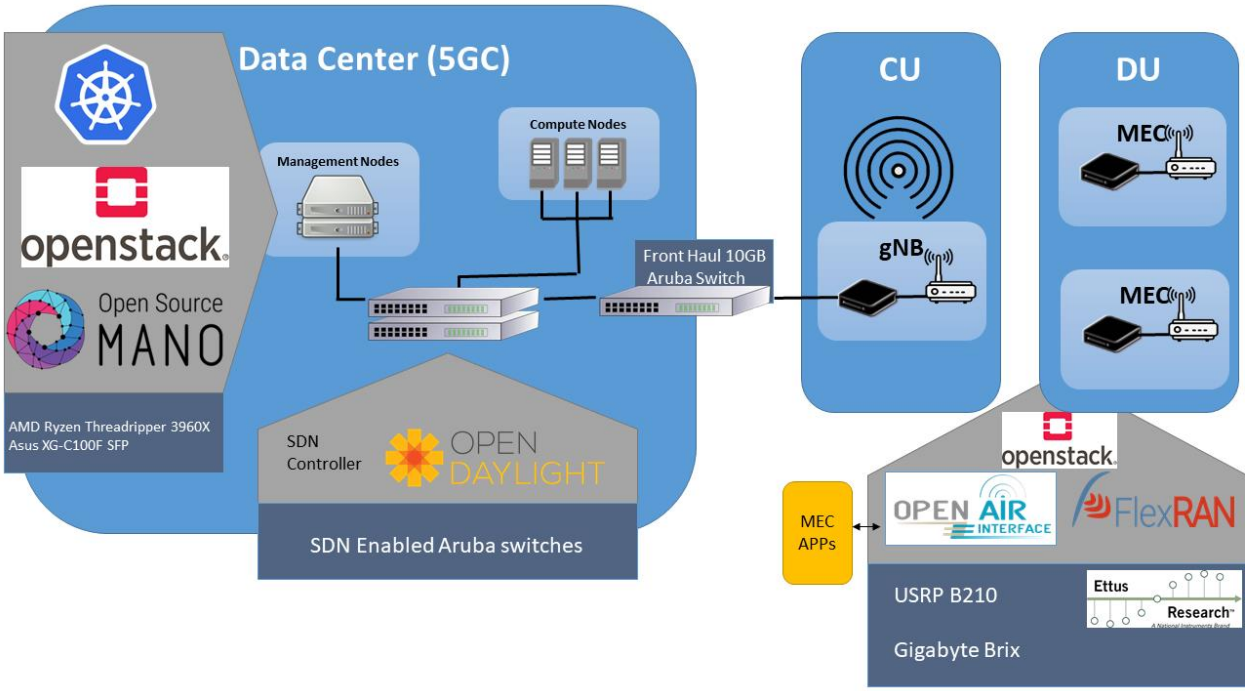
- ITI nZEB SmartHouse - Digital Innovation Hub
  - *9,57 kWp **Thin Film PVs** (Modbus enabled)*
  - *5 kWh Lithium Ion **Batteries** (Modbus enabled)*
  - *22kW **Charging Station** (OCPP enabled)*
  - ***Smart Elevator** // 5kW recuperation*
  - *Rain Water collection and redistribution as **Grey Water***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

5G Testbed (core & RAN)

- **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

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.

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CERTH-ITI
Reconfigurable Intelligent Surface

4.7 GHz RIS module:

- CERTH operates a **reconfigurable intelligent surface** comprising 256 elements.
- The **Controller** plays a central role in managing **beam steering** between the incident and reflected directions of the RIS.

- Controller

- **LAN Port**: Enables control via Ethernet (RJ45 interface).
- **SPI Proprietary Interface**: Supports rapid pattern switching.

  - AI-based **Anti-jamming & Anti-spoofing** (**RIS in V2X**)
  - **Human Activity Recognition Use case over RIS**

NAT WORK

AutoTRUST

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).

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fidal field trials beyond 5G

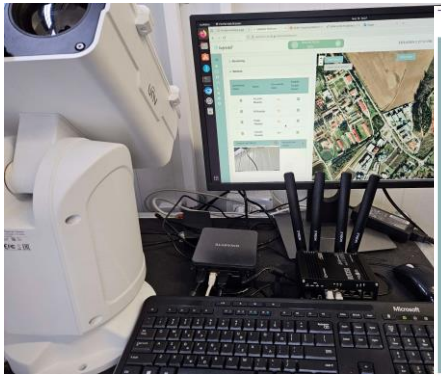
SwarmCatcher

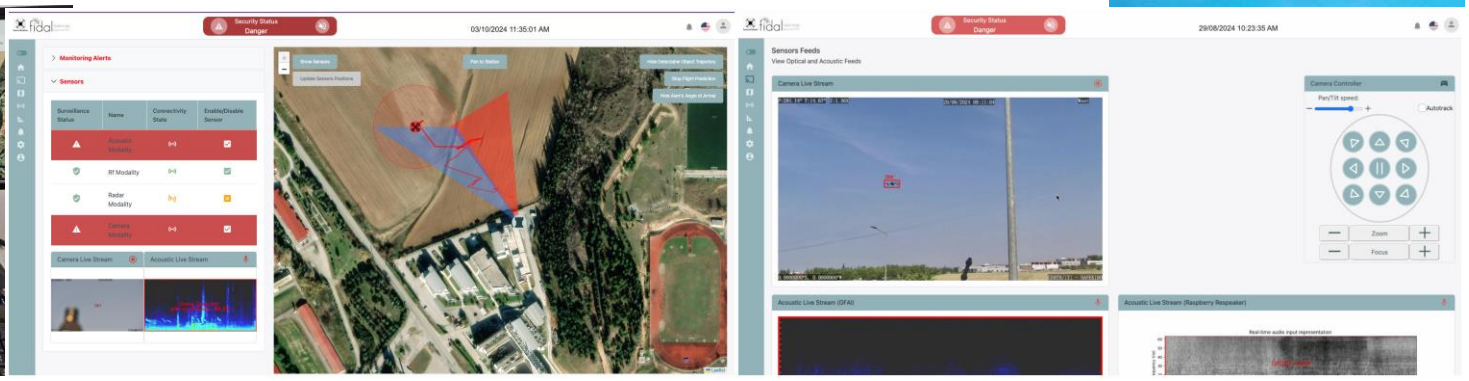
CERTH-ITI Anti-Drone Civil Protection augmented platform for detection, tracking identification and neutralization of unauthorized/hostile UAVs

– **Multiple-Sensor Grid On-board** for wide and multiple coverage
– **Advanced Monitoring Platform** for real-time **situational awareness**

Safekibo

SwarmCatcher (FIDAL 1st open call):
Anti-Drone Use case over 5G Testbed





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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)
13. **SwarmCatcher - (Coordinator)** - (1st FIDAL Open Call, HE-JU-SNS-2022-STREAM-D-01-01) - AI-powered Anti-Drone and Surveillance Experimental Infrastructure over Cloud-native 5G and Beyond Networks - (Anti-drone Physical security on 5G/6G networks)
14. **AutoTRUST - (Coordinator) –** (HORIZON-CL5-2023-D6-01-01) -Autonomous self-adaptive services for TRansformational personalized inclUsivenesS and resilience in mobility – Sensor fusion, Virtual assistant, AI-based security
15. **CoGNETs - (Coordinator)** – (HORIZON-CL4-2023-DATA-01) -Continuums Of Game NETs: swarm intelligence as information processing – End-to-end security mechanisms for IoT-to-cloud swarm continuums
16. **GuardAI - (Use Case Leader & Technical Partner)** – (HORIZON-CL3-2023-CS-01) -Enhancing Robustness and Security of Edge AI Systems for Safety-Critical Applications – AI-based cybersecurity & physical security on 5G networks and autonomous vehicles

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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

SANCUS

ARROW
Security for 5G and Beyond

ULTIMO

SAND BOX

SHOW
AUTOMATED URBAN MOBILITY

GuardAI

NAT W RK

ELECTRON

MONICA

nIoVe

ECHO

AVENUE
Autonomous Vehicles to Evolve to a New Urban Experience

NEMESYS

SDN-µSense

SMILE

FORTIKA
Cyber Security Accelerator for trusted SMEs IT Ecosystems

KONFIDO
Secure and Trusted Paradigm for Interoperable eHealth Services

ZEROSWARM

SPEAR

SERIOT

GHOST

Member & active contributor of

ECS
EUROPEAN CYBER SECURITY ORGANISATION

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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

SANCUS

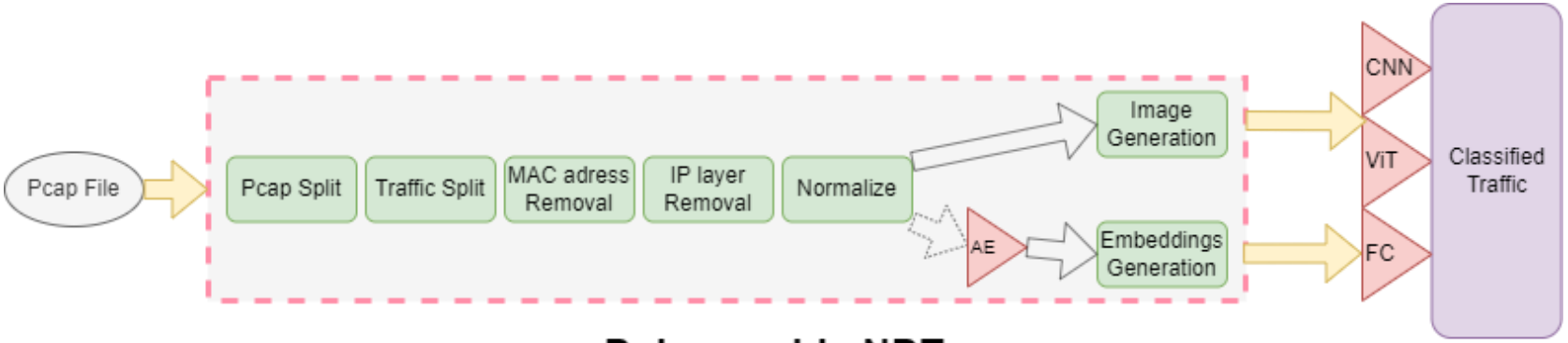
ARROW
Security for 5G and Beyond

NAT WORK

SAND BOX

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

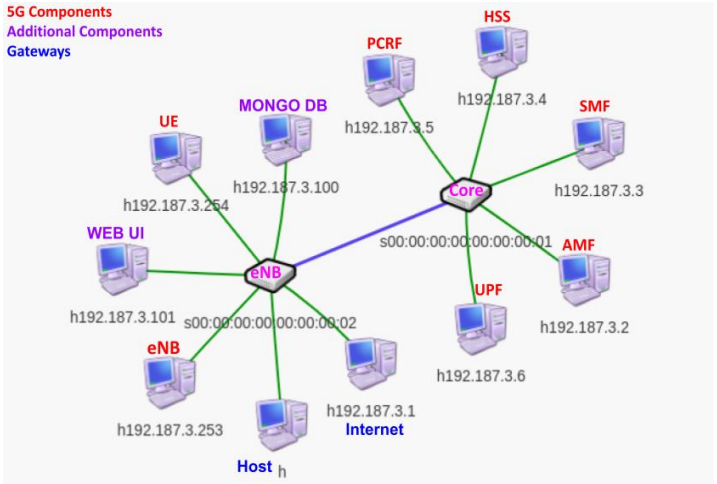
- Utilize **NLP** based techniques to derive .pcap embeddings (**packetToVec**)
- Generate embedding via BERT models (**MalBERT**)
- Make use of **memory** in looking for patterns by replacing regular autoencoders with **LSTM** autoencoders



Polymorphic NPT

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



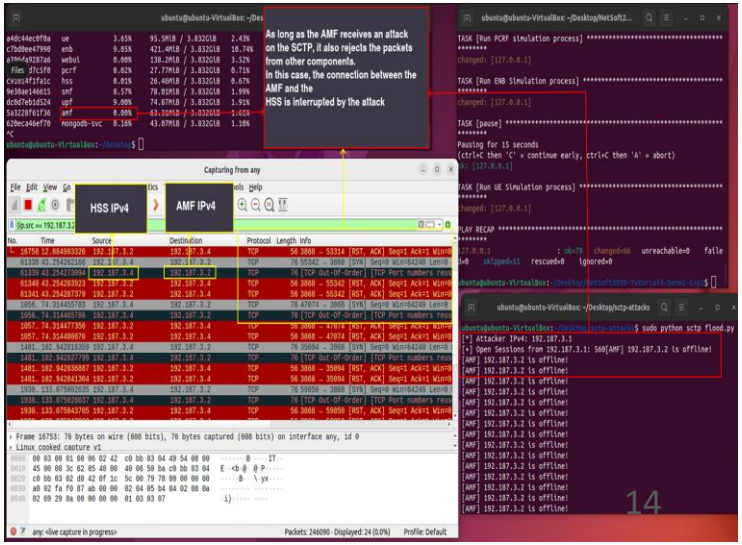
SANCUS

ARROW
Security for 5G and Beyond

SAND BOX

NAT WORK

- **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.



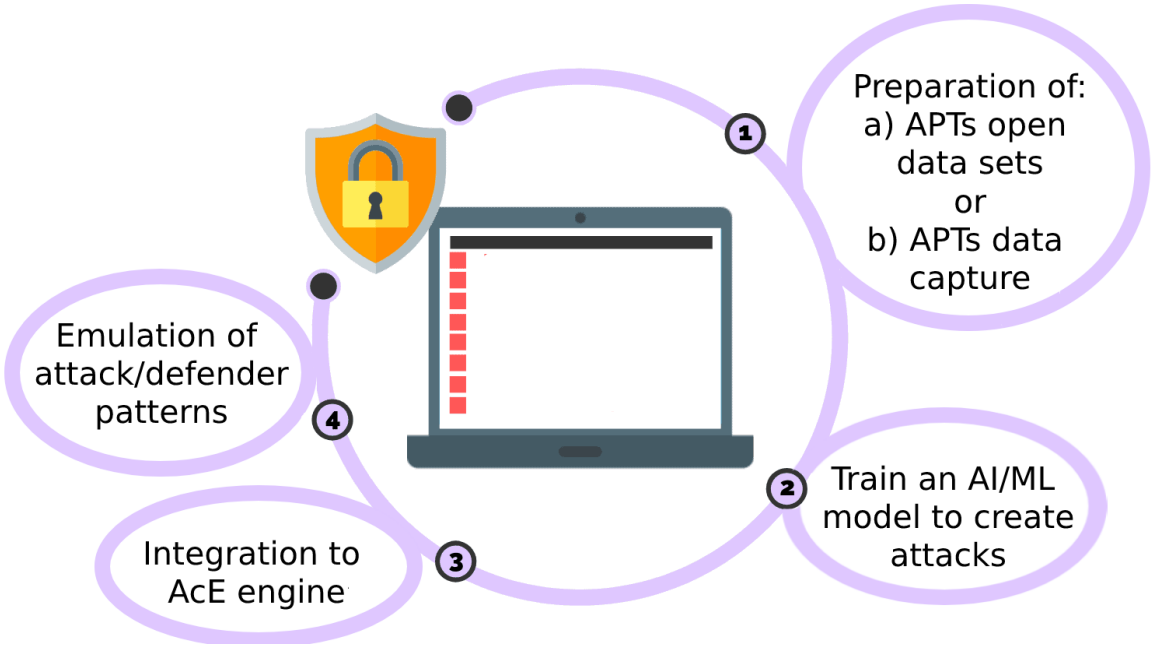
AI-based Penetration Testing in 5G

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



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V2X Enablers

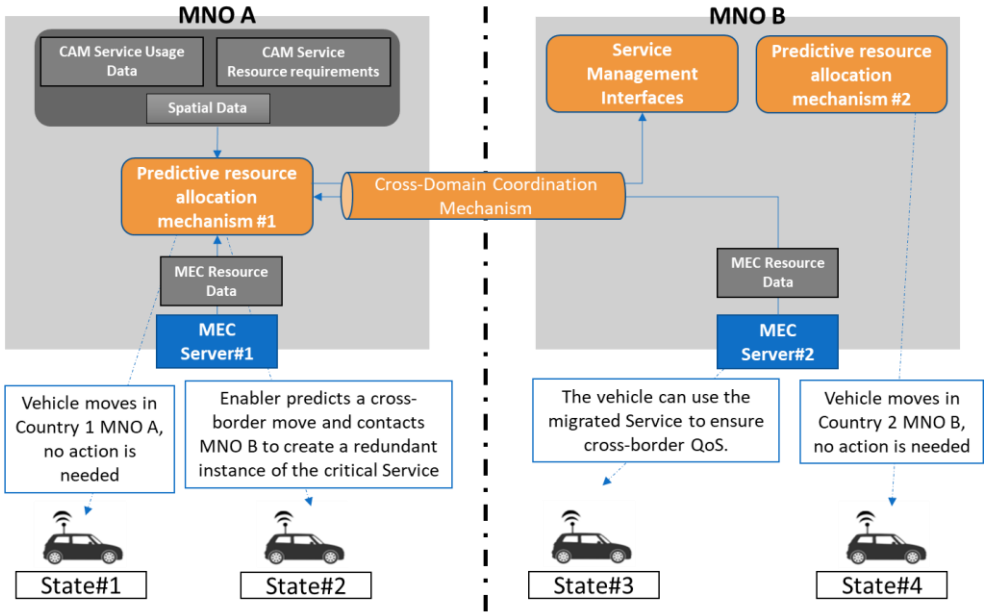
Predictive resource allocation of V2X related network functions using AI algorithms

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:
  a) initially **predict future vehicle location** and then
  b) **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.



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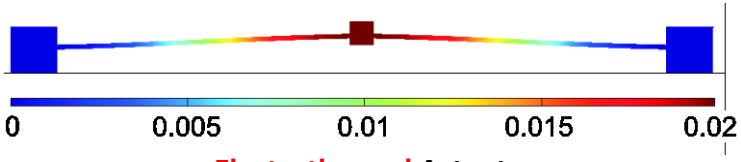
Multiphysics Simulations

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

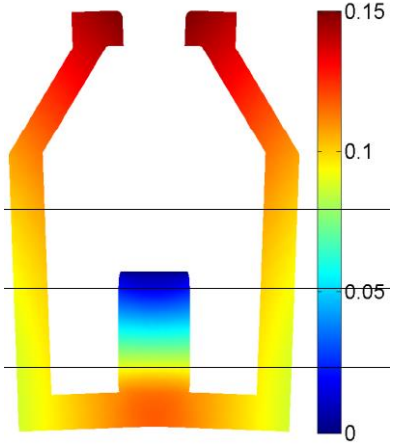
Static FEA with objectives of:

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

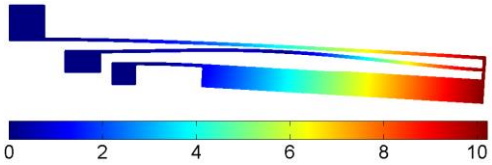


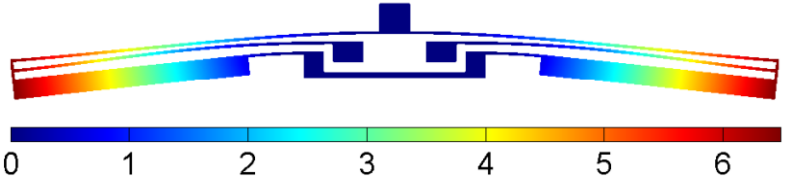
Electrothermal Actuator

Piezoelectric Micrigripper

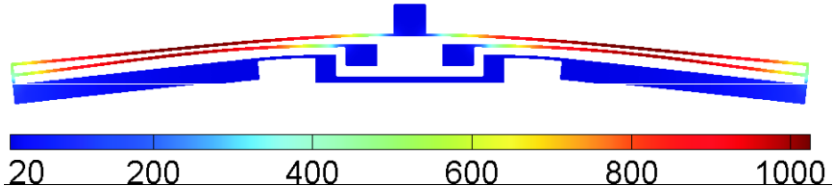


Two-Hot-Arm Electrothermal Actuator





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



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

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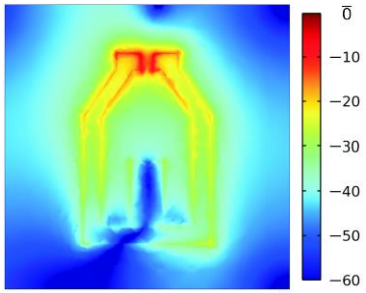
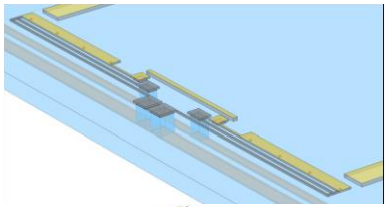
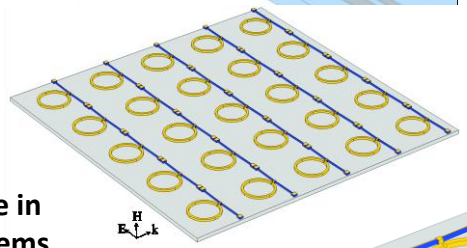
Computational Electromagnetics

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



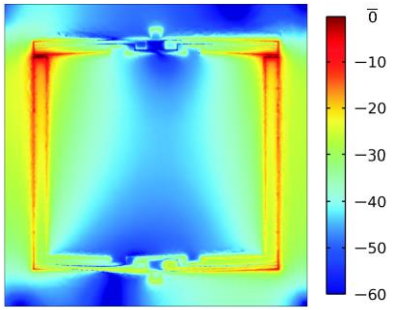
Electric Field on Microgripper Split Ring Resonator (SRR)



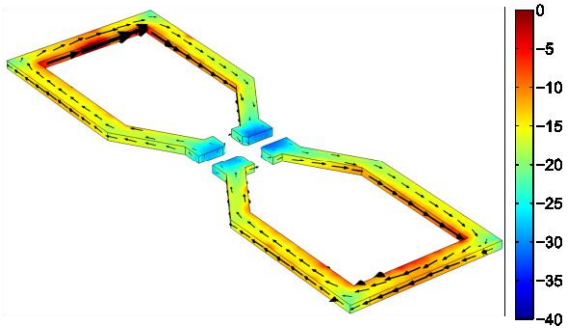


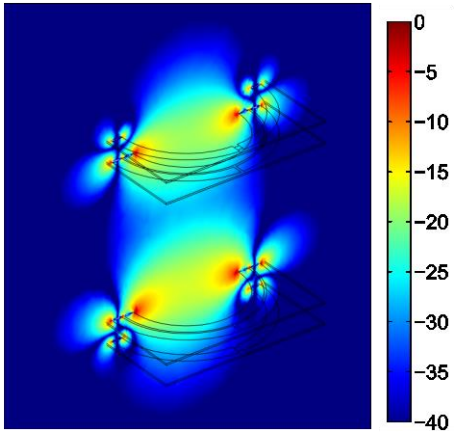
Magnetic Resonance in Wireless Power Systems

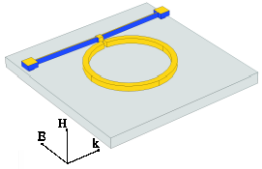
Electric Field on Double Two-Hot-Arm SRR

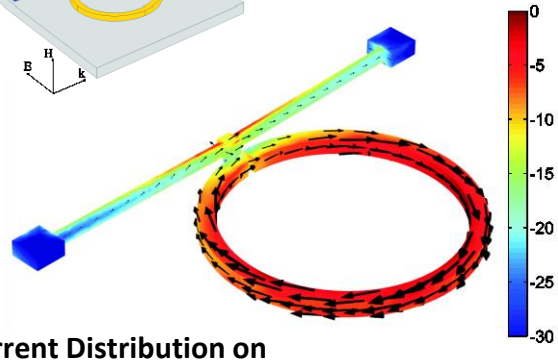


Current Distribution on Microgripper based Metasurface Unitcell







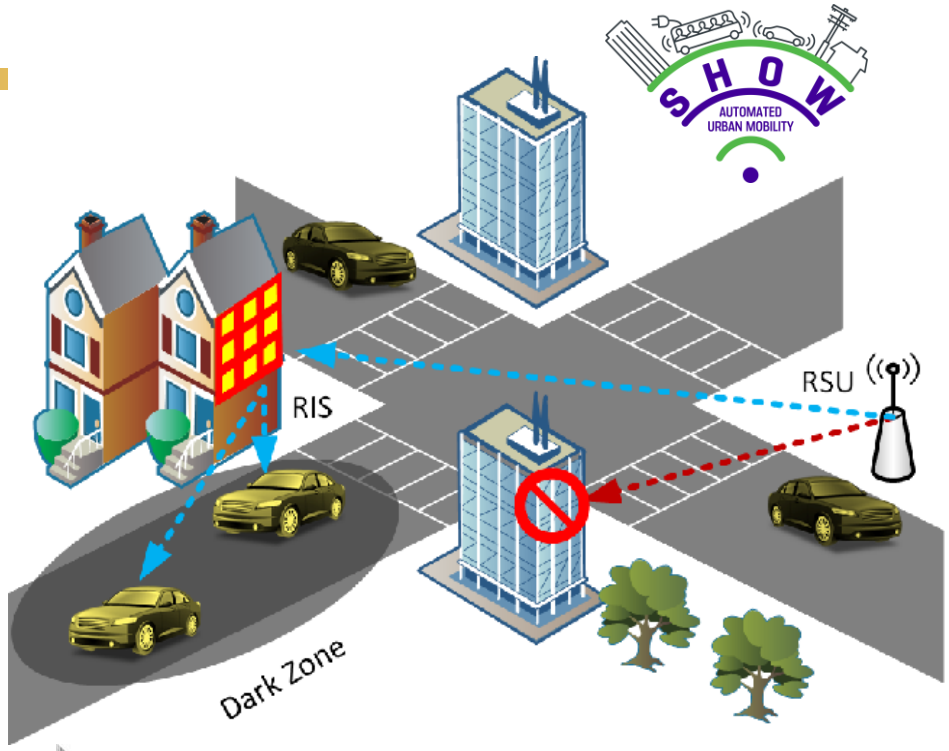


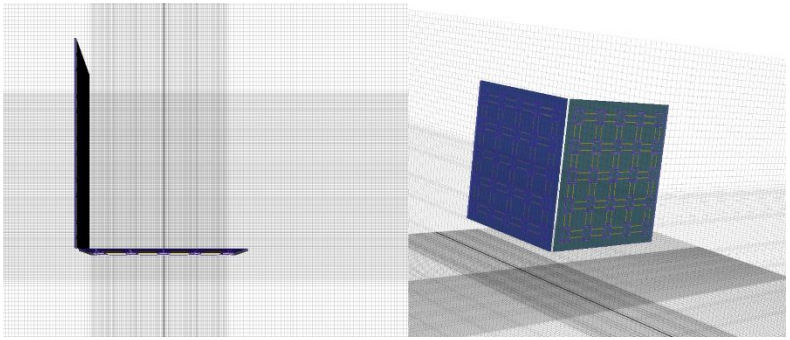
Current Distribution on Electrothermal based Omega SRR

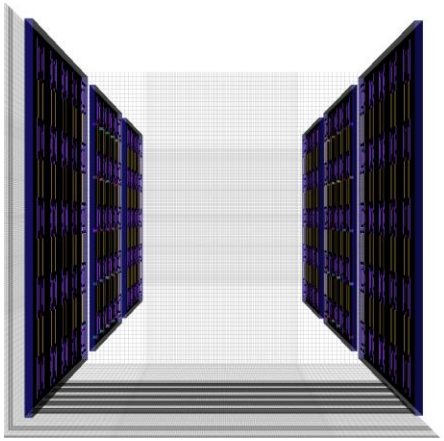
Reconfigurable Intelligent Surfaces

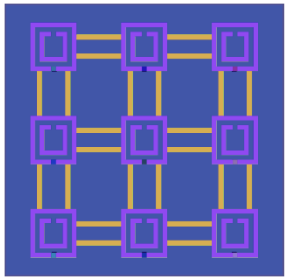
Uses cases of RIS in V2X:

- **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**









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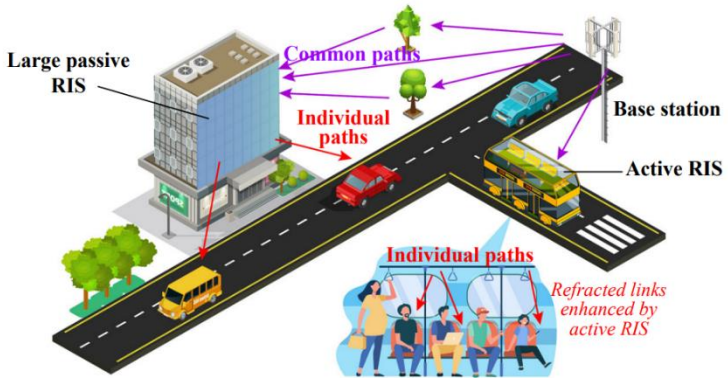
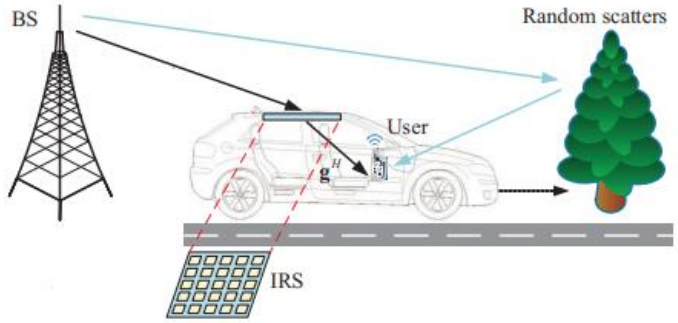
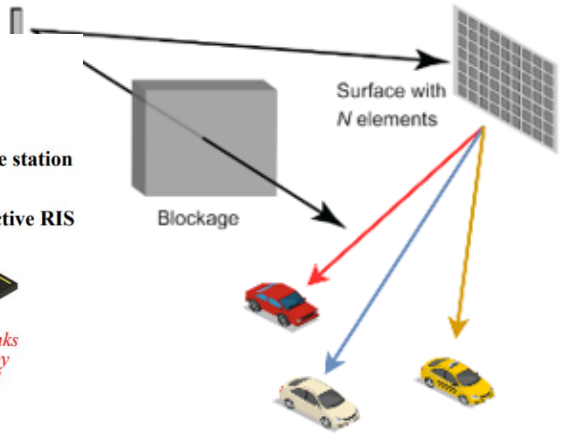
Reconfigurable Intelligent Surfaces



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

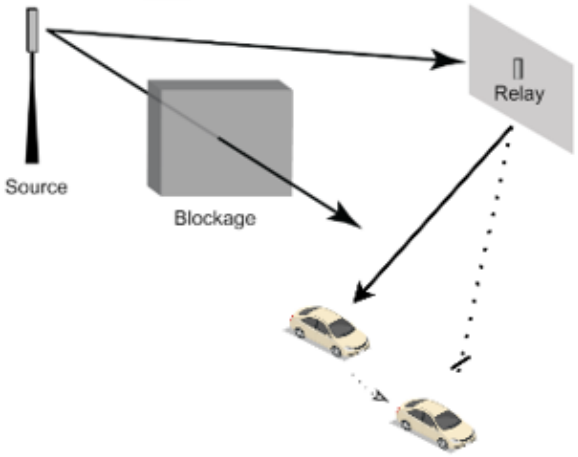


Using RIS

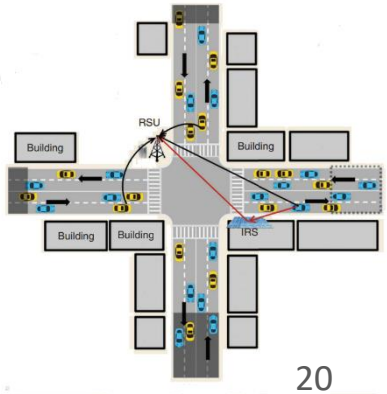


- RIS unit can both send and receive a signal **at the same time.**
- RIS supports beamforming in numerous directions.

Using Relays



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



ULTIMO

NAT WORK

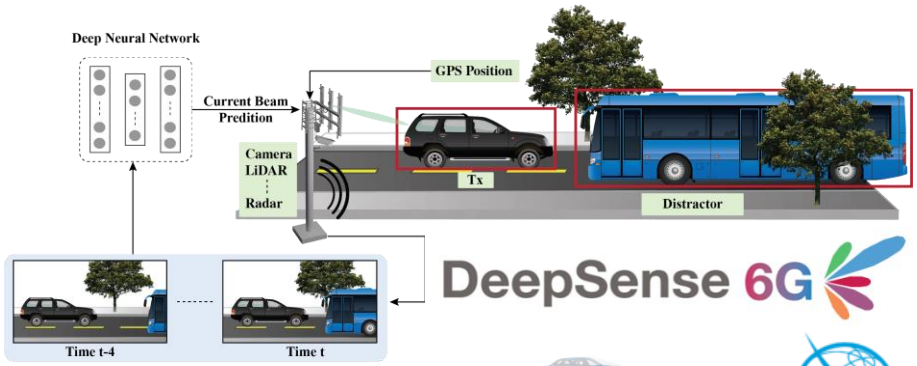
CERTH-ITI in DeepSense 6G Challenge

Information Technologies Institute

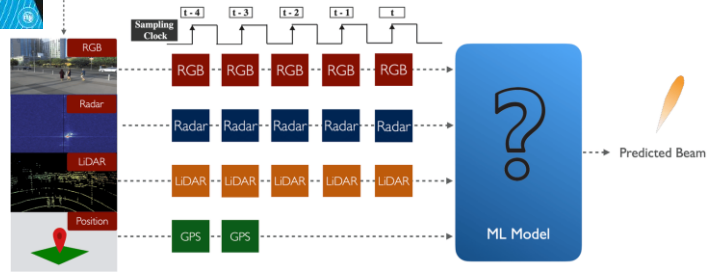
ULTIMO

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**.

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



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



Ranking: 5th Place for ULTIMO Team (Top 5)

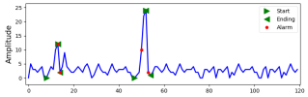
For a new late fusion model for the **simultaneous solution** of the double problem of **Beam Classification-categorization - Blockage Classification -- extension**

Research interests

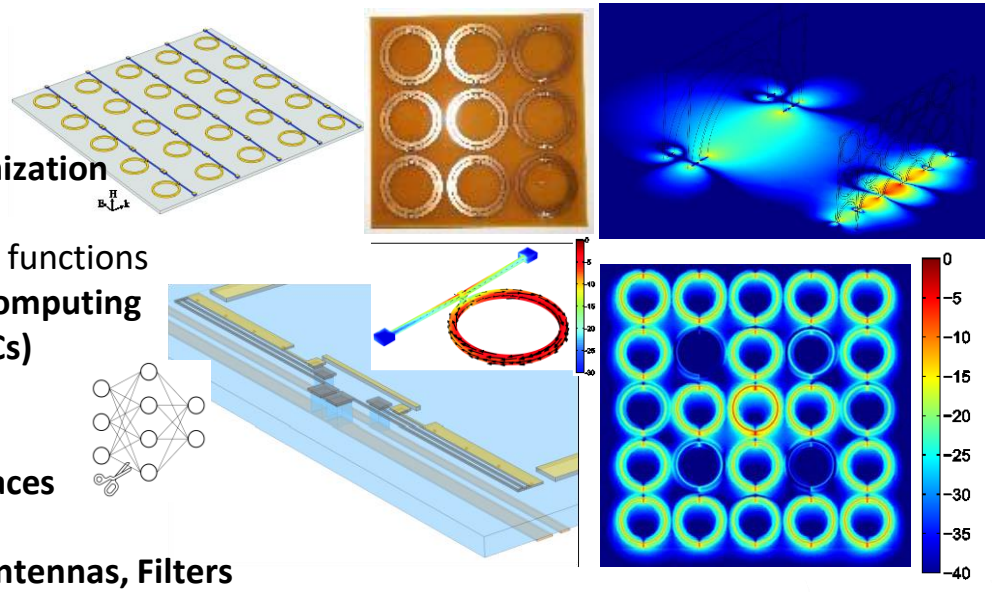
Expertise Offered

Information Technologies Institute

- 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) & ISAC**
  - 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, anti-drone, PPDR)
  - **Smart home** infrastructure & **EMF exposure** prediction



Member & active contributor of

Information Technologies Institute

SNS 2025 Research interests

Expertise Offered

HORIZON-JU-SNS-2025-STREAM-B (RIA)

- **01-01: Advanced Architectures Systems and Technologies**
  - New architectural solutions: New design approaches for 6G system architecture systems
  - Deep learning models:
    - **AI optimization** under energy and/or under security constraints
    - **Constrained deep learning** by incorporating constraints into the learning process
  - Real time serverless computing: **Provisioning and orchestration algorithms** for database and storage services
  - Autonomous Cognitive Agents: **AI-powered and LLMs-based multi-agent** systems
  - Goal-oriented Communication: **Generative AI** technologies on device level

- **01-02: Advanced IoT and Device Technologies**
  - Sensing and connectivity to enable zero energy devices: **Energy harvesting** with **reconfigurable surfaces**
  - Communication technologies and architectures enabling 6G unlicensed operations for IoT:
    - **Provision of use-cases**: industrial environments, healthcare/hospital deployment, campus networks
    - Data processing over a computing continuum: **Data acquisition and generation, repositories, curated training and evaluation data**
  - IoT applications that can benefit from 6G characteristics:
    - **AI-based optimization** based on 6G features of diverse applications
    - **AI-powered physical layer** evolutions (MIMO, RIS) and **design** of novel connected IoT devices

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SNS 2025 Research interests

Expertise Offered

HORIZON-JU-SNS-2025-STREAM-B (RIA)

- **02: Wireless Communication Technologies and Signal Processing – Standardisation and Follow-up/PoCs**
  - Physical layer technologies for enhanced spectral efficiency: **energy-efficient new waveform design**
  - Energy-efficient implementation of key **physical-layer algorithms and channel estimation**
  - Improved lower layer signaling in 6G Air Interface and **physical-layer security**
  - Holographic beamforming and novel **beam management schemes** in massive MIMO and RIS
  - Integrated sensing and Communication (**ISAC**)
  - **Cell-free MIMO technologies** and architectures for improved coverage, reliability and mobility support
  - **AI framework for RAN networks** by using AI/ML for the lower layers of the protocol stack
  - AI-assisted multi-user and **massive-MIMO systems** channel coding aspects
  - Reduction of power consumption in the RAN or **multi-modal model training** for improved radio/network efficiency
  - Conflict and **anomaly detection and resolution**
  - **Trustworthy/safe/explainable AI** and the exploitation of **generative AI** for RAN optimization
  - Spectrum sharing and re-use for **sustainability**
  - **AI/ML powered automation** and optimisation, **micro-orchestration of RAN functions**
  - Integration of multi-processor SoC/accelerators and heterogeneous **resource management**

- **03-01: 6G NTN-TN Unification/Integration**
  - **Security and resilience** optimisation at system and subsystem level
  - Public safety use-cases: **anti-drone, anti-jamming**
  - Ultra-high energy efficiency especially in optical networks (**AI/ML approaches**)
  - 3D networking for 6G networks (**SDN, resource allocation, security aspects**)

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SNS 2025 Research interests

Expertise Offered

HORIZON-JU-SNS-2025-STREAM-B (RIA)

- **03-02: Higher Speed Optical Access Networks and future end-to-end Packet Optical Network Architecture in 6G**
  - **AI support for network automation** and efficient use of resources (energy consumption and efficiency)
  - Quantum networking over fiber for **trustworthy systems** and applications
  - Impact of photonic systems in 6G on **energy consumption / sustainability**

- **04-01: Smart Security / Security Services**
  - Security Services and Security attributes of 6G services: **Security evaluation**, exposition of Security attributes
  - **User-centric security**, advanced security schemes applicable to 6G APIs
  - Seamless integration of **Managed Security Service Providers** into the 6G architecture
  - Continuous **security assessment** (in all phases of the system life cycle)
  - Development of **standardized metrics** to evaluate security quality
  - Design of **appropriate certification frameworks**, and secure coding practices
  - **Vulnerability management** during development

- **04-02: Reliable Services Operation**
  - End- to-end **attack detection and response** in 6G with **secure AI, self-healing and proactive defence** methods,
  - **Cyber Threat Intelligence (CTI)** platform specifically tailored to the 6G
  - Development of optimal algorithms addressing **energy efficiency, privacy aspects, and AI-usage limitations**
  - Exploitation of (distributed) **trusted AI/ML for 6G infrastructures**
  - **Cooperative remediation** of various type of failures/attacks and smart and **trustworthy service frameworks**
  - **Service auditing mechanisms** and zero-touch integrated **security deployment**
  - **AI-powered** attack generation and **penetration testing**

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SNS 2025 Research interests

Expertise Offered

HORIZON-JU-SNS-2025-STREAM-B (RIA)

- **05: Microelectronic – Front-End Module (FEM)**
  - Design supporting Integrated Communication and Sensing application and including **secure ICAS specific functions** at digital or RF level.
  - **Evaluation of use of ML/AI** for Tx/Rx for 6G performance, low cost, low energy consumption solutions.
  - **Analog neural networks** processing technology: **Neuromorphic and photonic computing**
  - **Minimisation of interferences** and support of efficient interference control: **anti-jamming technologies**
  - Availability of **large-scale data sets and training sequences** as part of open repositories.

HORIZON-JU-SNS-2025-STREAM-C (RIA)

- **01: 6G Telco Cloud and Service Provision Enablers**
  - Support advanced **6G applications and use cases** to contribute to core KVI's, and **sustainability**
  - Radio development for advanced networks including 6G Radio Access Network (RAN) architectures, **network orchestration models**, Massive MIMO.

HORIZON-JU-SNS-2025-STREAM-D (IA)

- **01: SNS Trials and Pilots (T&Ps) with Verticals**
  - **Emergency and Safety Services (PPDR), CCAM, Health, and Industry verticals**
  - **Cybersecurity framework for verticals**
  - Optimize energy consumption, **EMF exposure**, **trustworthiness**, privacy

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Open for Collaboration!

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Membership in Large Clusters & Initiatives

HYPERLEDGER

INTERNATIONAL DATA SPACES ASSOCIATION

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Universities / Research Centers

Industry / SMEs

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International Cooperations (Indicative List)

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NEW YORK UNIVERSITY
United States

OPEN UNIVERSITY OF CYPRUS

MONASH UNIVERSITY
Australia

University of Cyprus

INDUSTRY / SMEs