Edge AI for the Internet of Things: Insights from Real-World Projects

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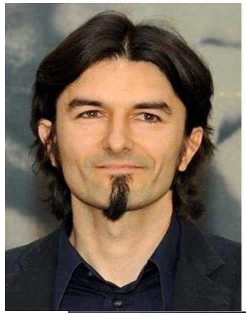
27. October 2025, ICTP, Trieste



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The Institute of Artificial Intelligence R&D of Serbia

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Founding director of ICONIC centre

ICONIC: Centre for intelligent communications, networking and information processing

https://iconic.ftn.uns.ac.rs/

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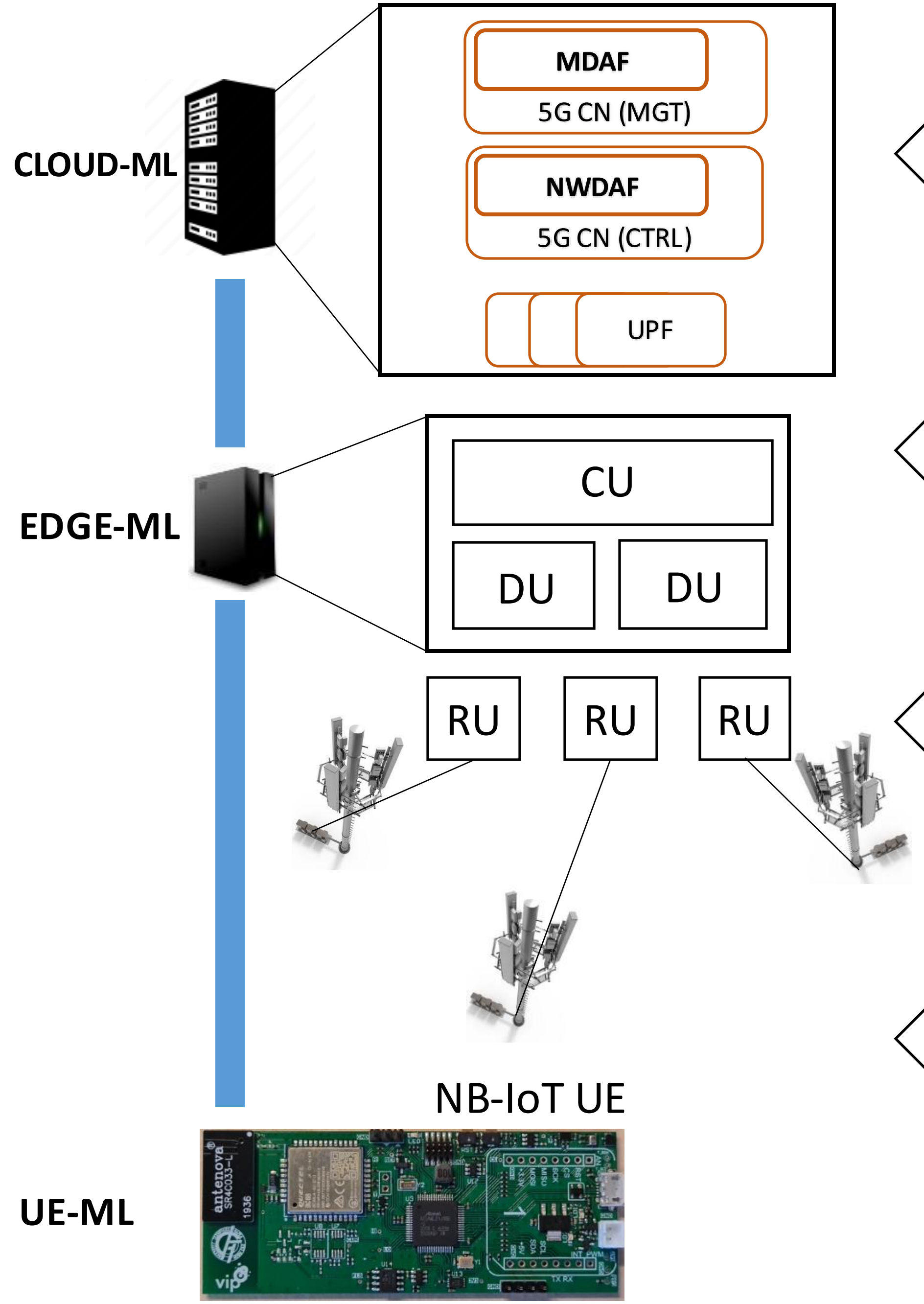
Communications and Signal Processing

Electronics



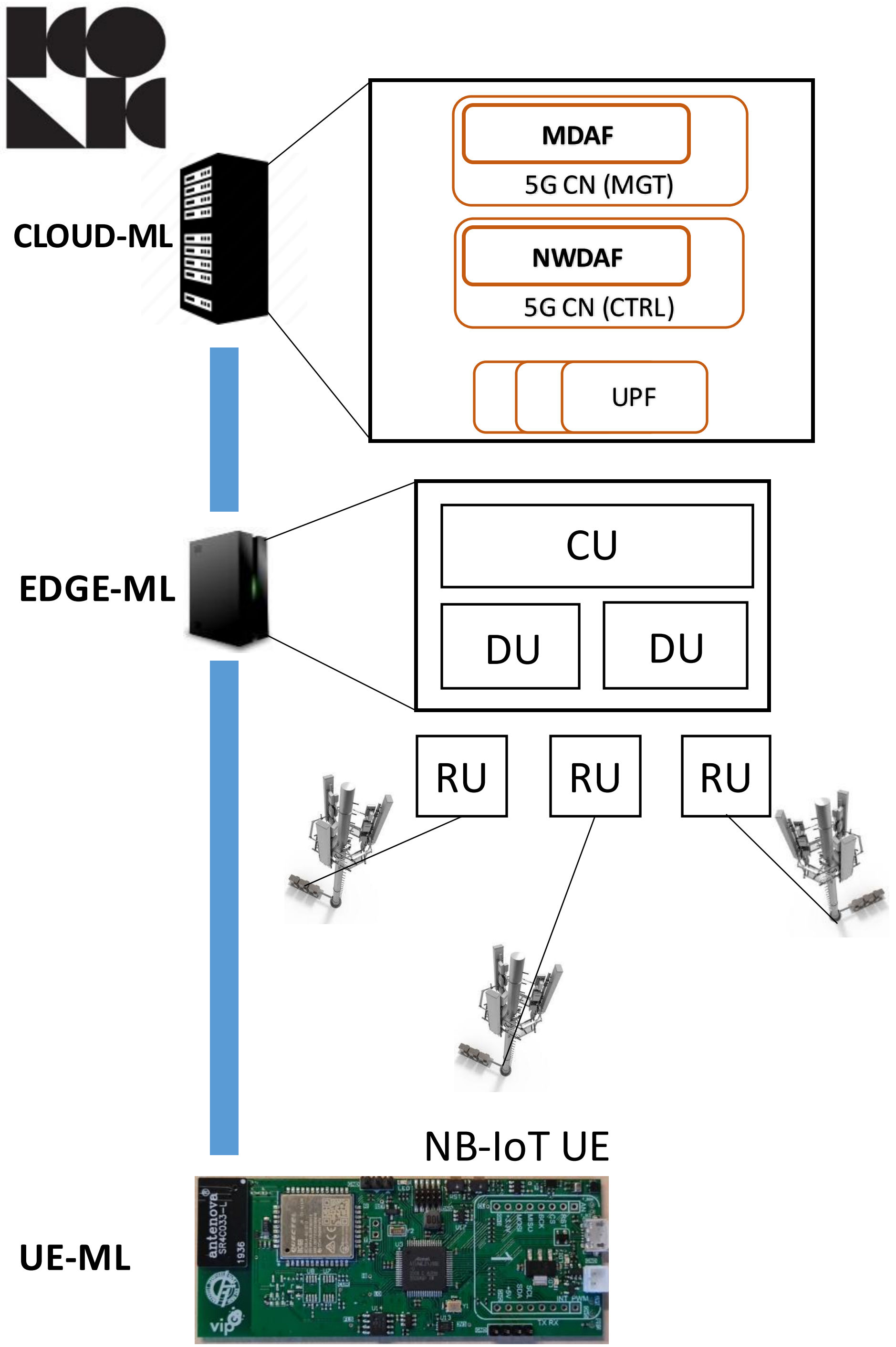
Centralised vs distributed ML/AI deployment in networks
- Delay vs accuracy vs convergence
- Communication costs and complexity

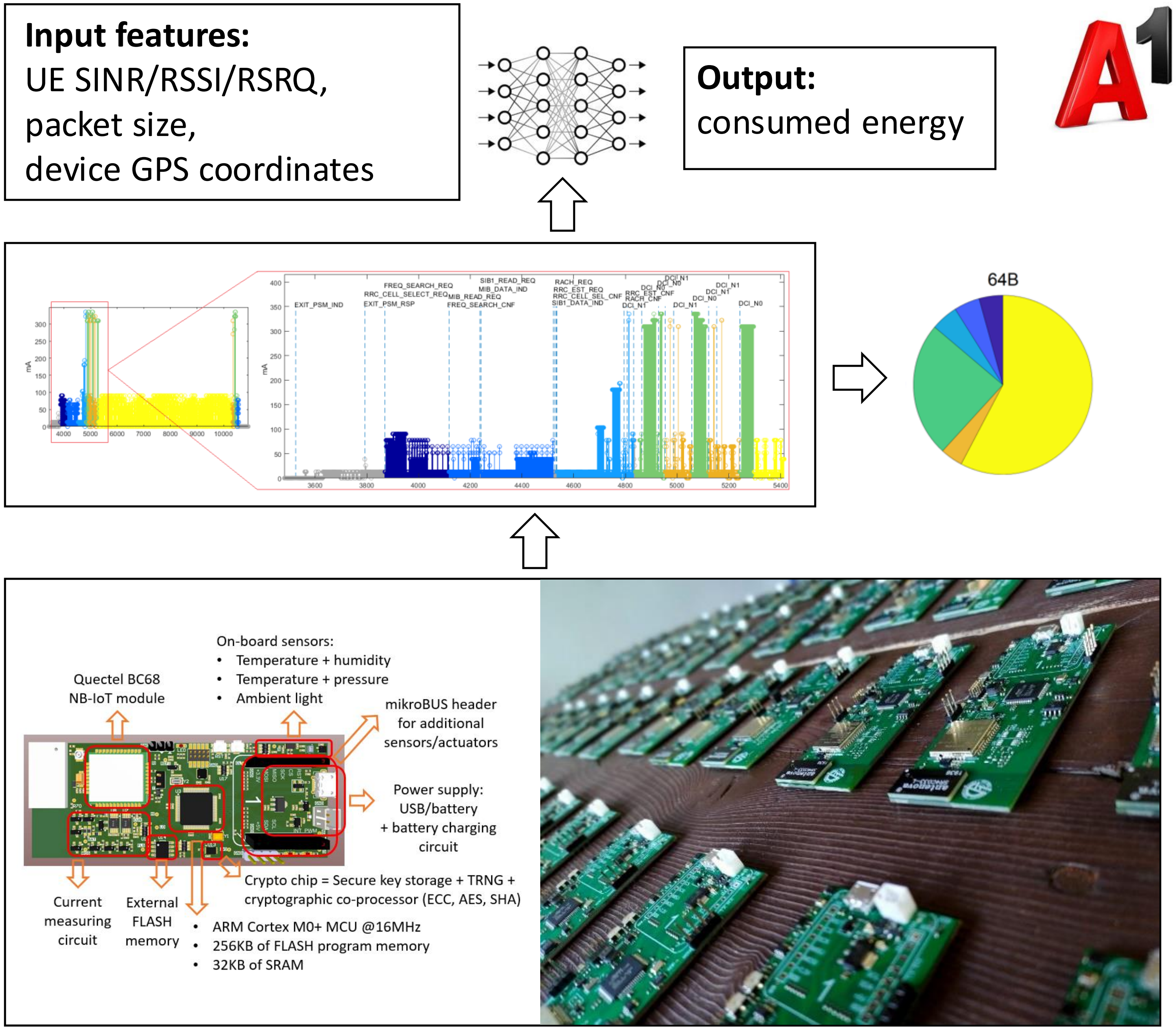
Large-scale distributed inference/optimisation in networks
- Large-scale Graphical models and Belief Propagation
- Message-passing Graph neural networks

Machine learning for the PHY layer
- Classical signal processing vs ML-based PHY layer
- Autoencoder-based PHY design

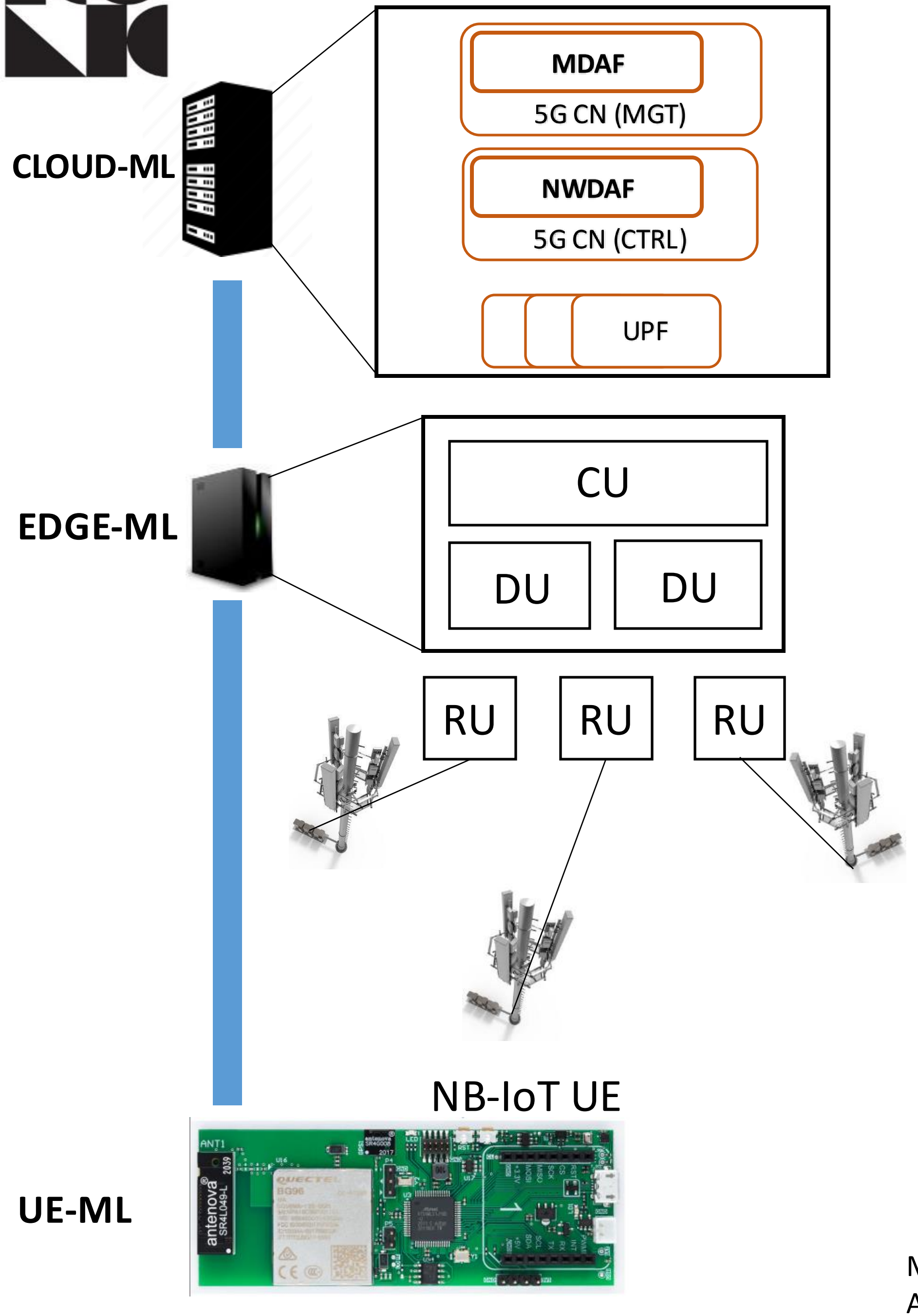
Fundamental limits of massive connectivity
- Random access design for massive IoT
- Reliability vs Age of information

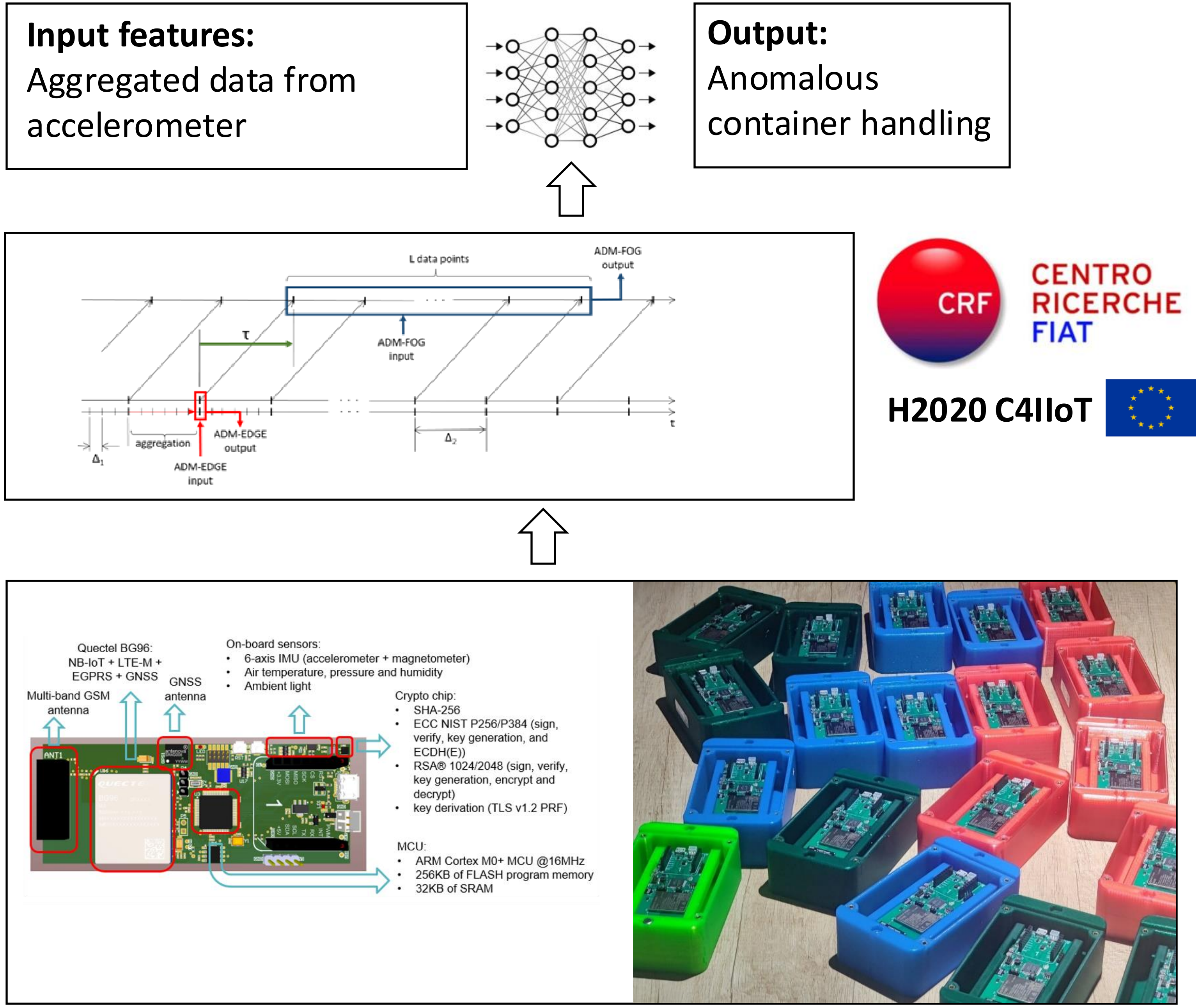
Machine learning at the Edge
- Low-complexity ML (TinyML)





V. Nikic, D. Bortnik, S. Sobot, D. Vukobratovic, I. Mezei, M. Lukic: "Evaluation of Machine Learning Algorithms for NB-IoT Module Energy Consumption Estimation based on Radio Channel Quality," IEEE Access, 2025.

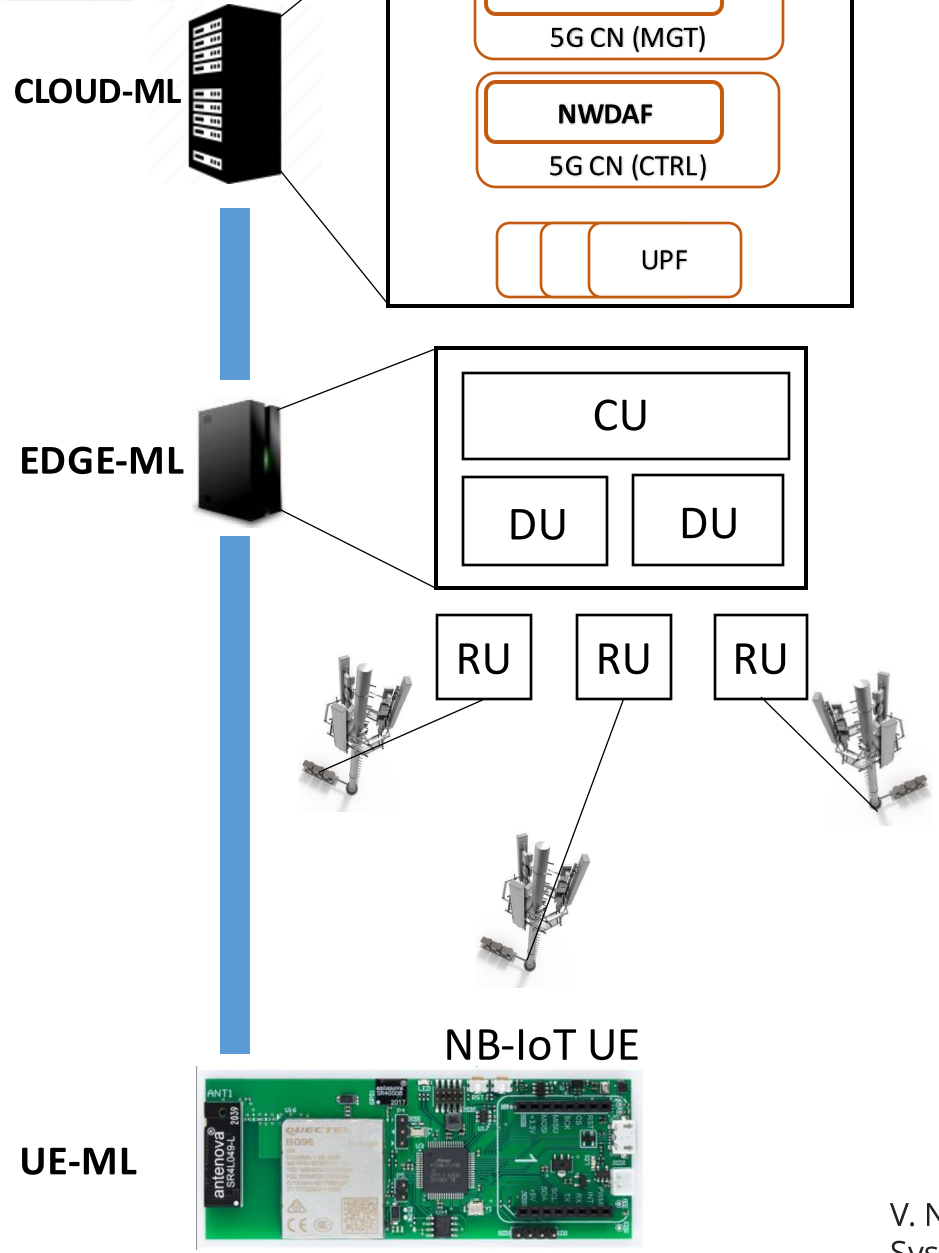


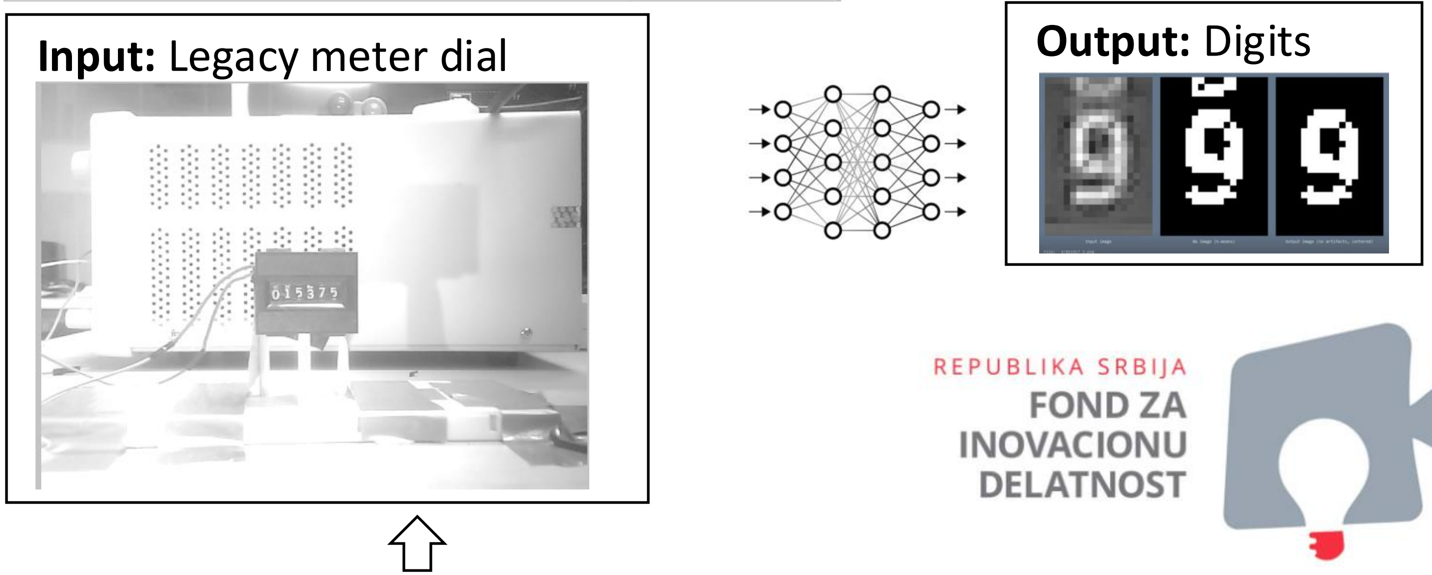


CENTRO RICERCHE FIAT

H2020 C4IIoT

M. Savic, M. Lukic, D. Danilovic, Z. Bodroski, D. Bajovic, I. Mezei, D. Vukobratovic, S. Skrbic, D. Jakovetic: "Deep Learning Anomaly Detection for Cellular IoT with Applications in Smart Logistics," Vol. 9, pp 59406-59419, IEEE Access, April 2021.





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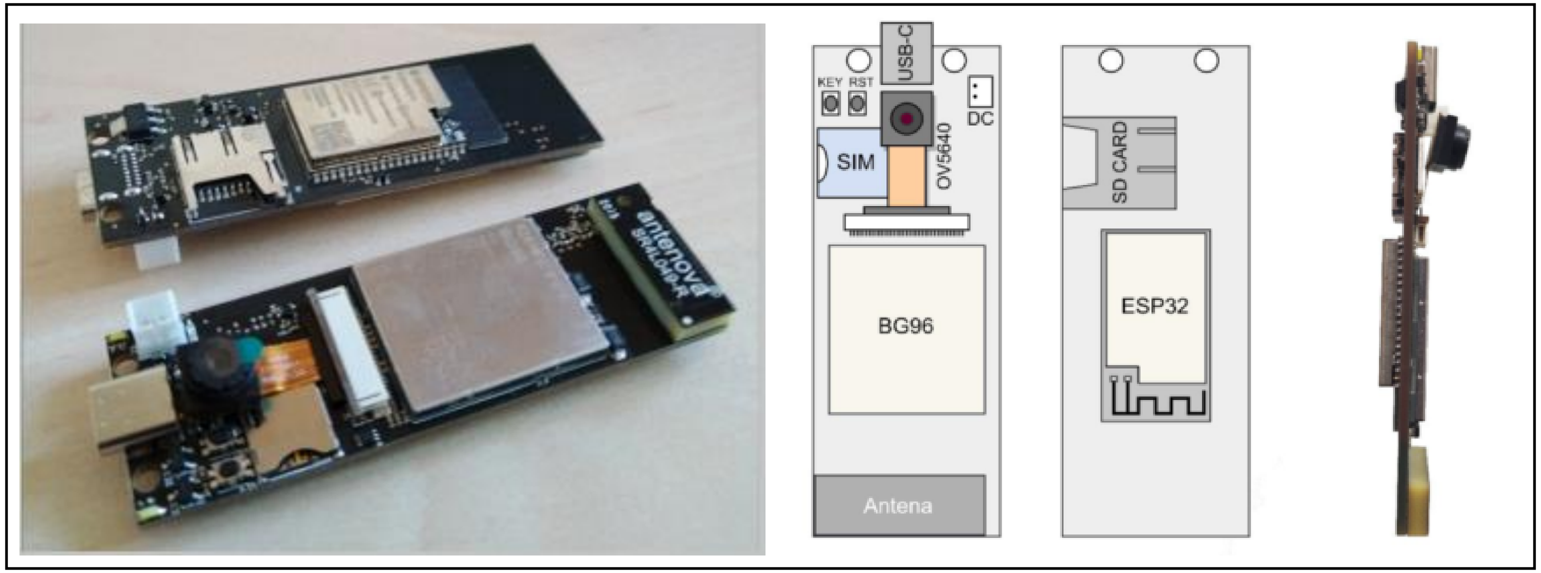
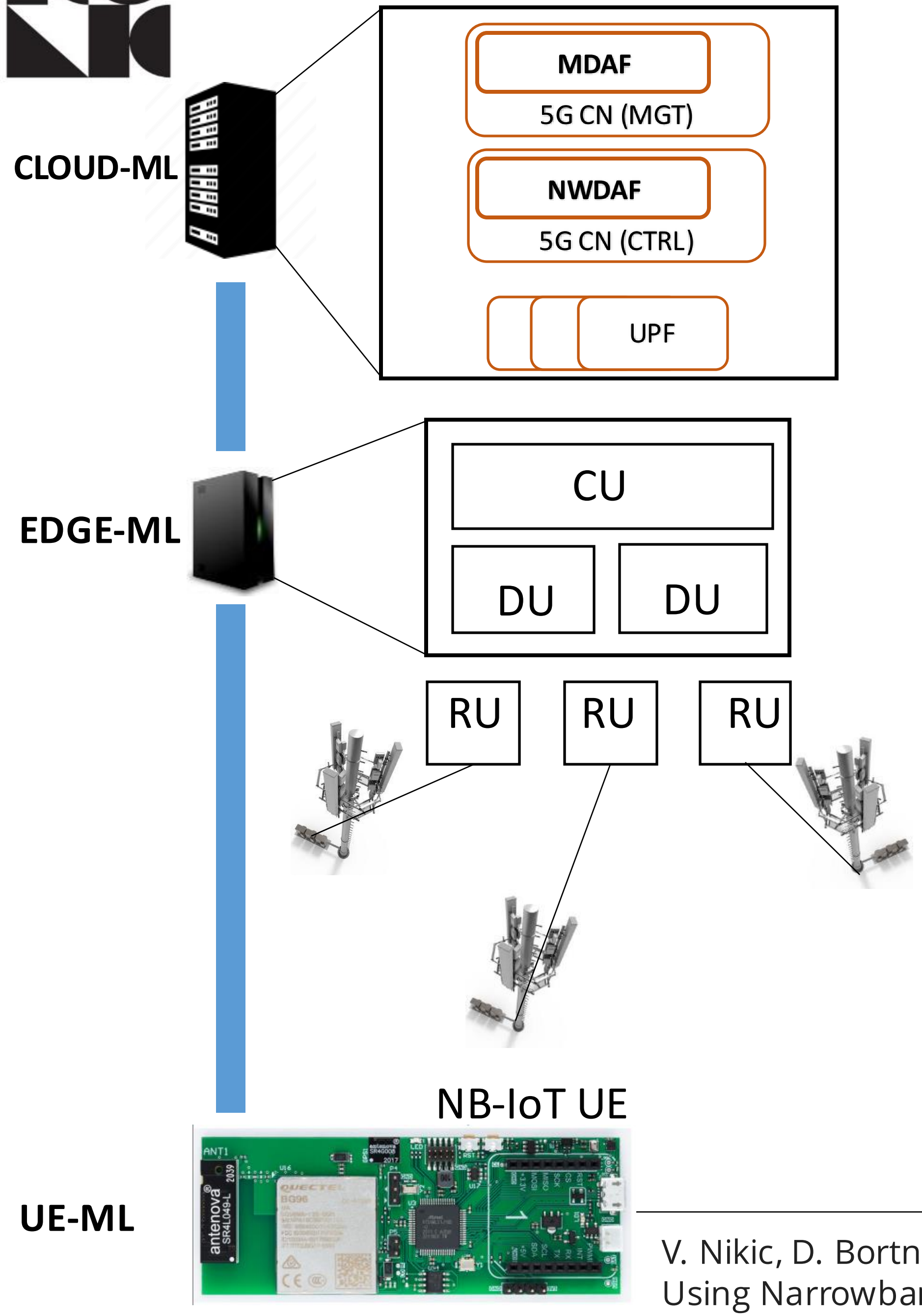
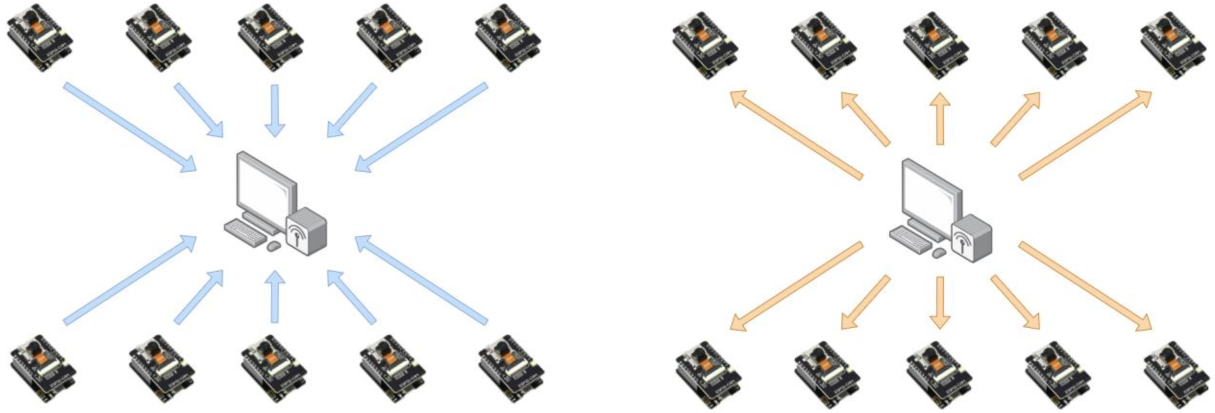


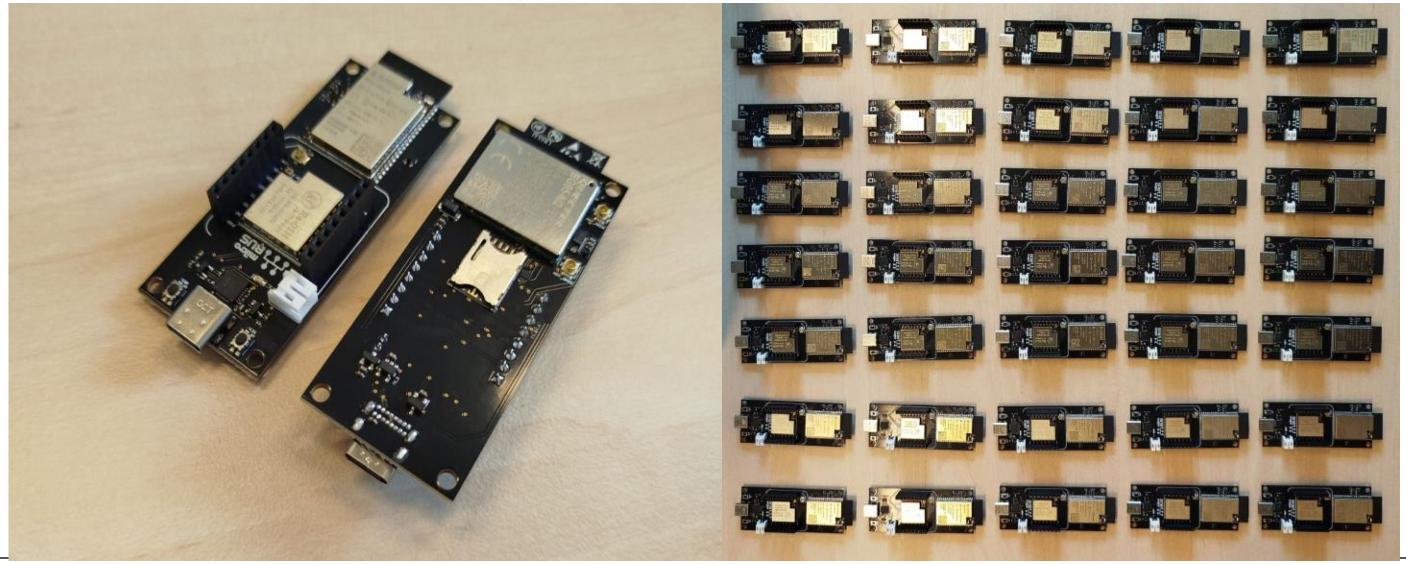
V. Nikic, D. Bortnik, M. Lukic, D. Vukobratovic, I. Mezei: “Lightweight Digit Recognition in Smart Metering Systems Using Narrowband Internet of Things and Federated Learning,” **Future Internet**, 16(11), 402, 2024.

Distributed Collaborative Learning:
Split vs Federated Learning for Massive IoT

TinyML implementations on real-world devices







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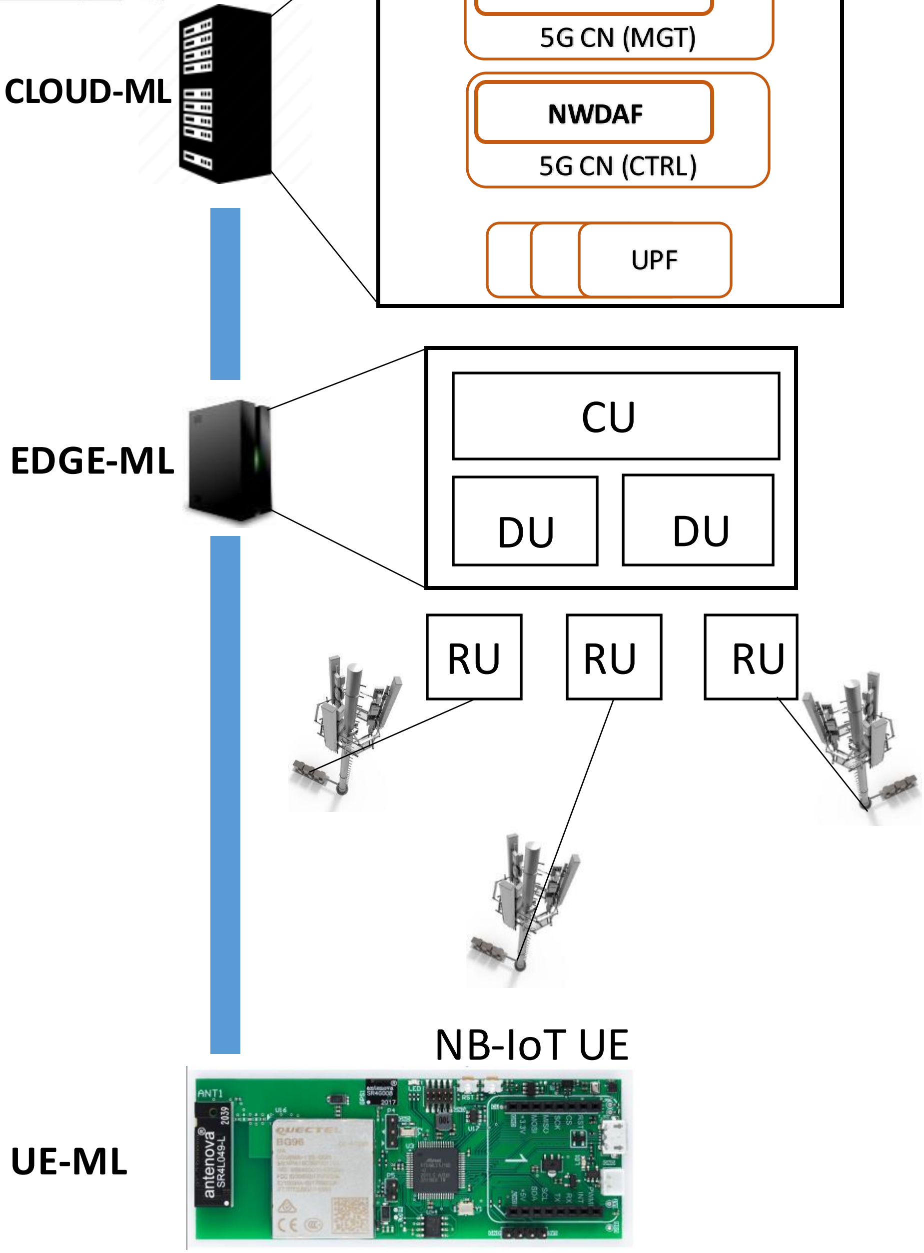
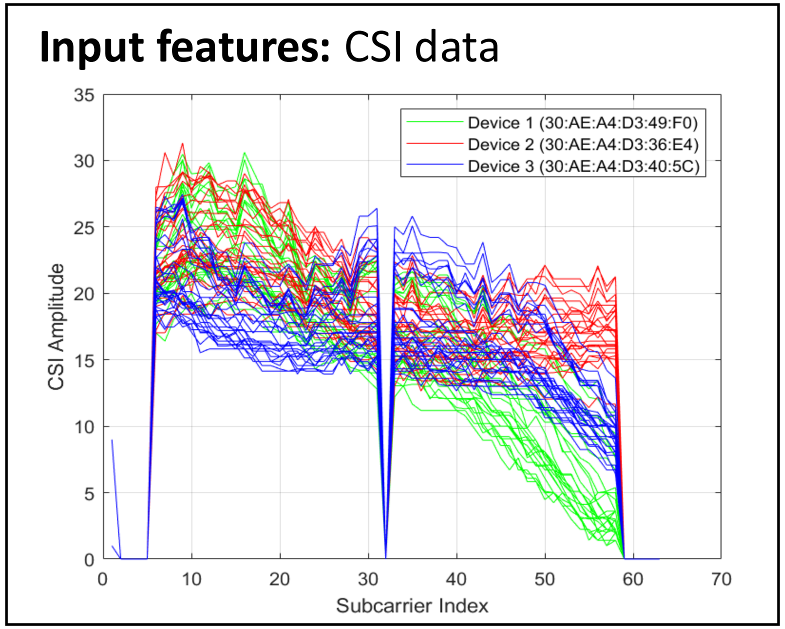
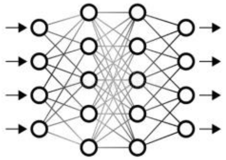






Output:
Device ID
via CSI data

STELLANTIS

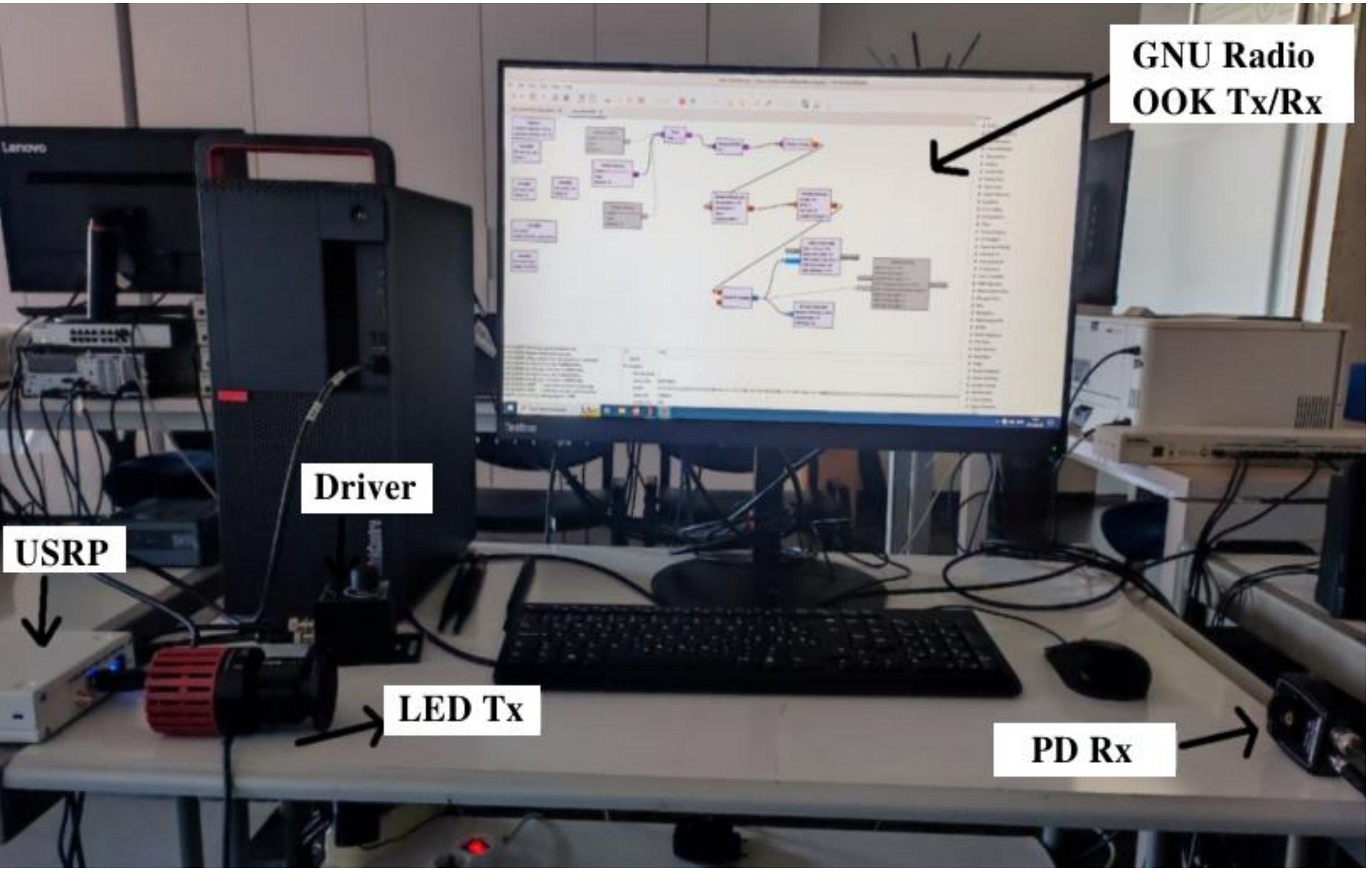
H2020 COLLABS

D. Vukobratovic, M. Lukic, I. Mezei, D. Bajovic, D. Danilovic, M. Savic, Z. Bodroski, S. Skrbic, D. Jakovetic: "Edge Machine Learning in 3GPP NB-IoT: Architecture, Applications and Demonstration," EUSIPCO 2022, Belgrade, Serbia, August 2022.

Hybrid Indoor OWC/Outdoor LoRa IoT System

Design of hybrid indoor IoT/outdoor LP WAN (LoRa) connectivity:

- USRP-based OWC prototype (Figure) + LoRa
- IR-based OWC prototype (Figure)
- OpenVLC-based prototype



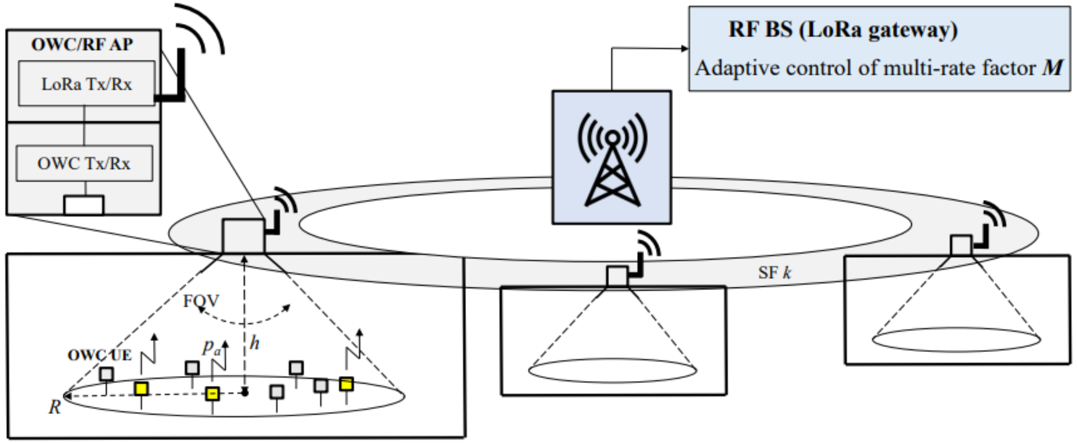
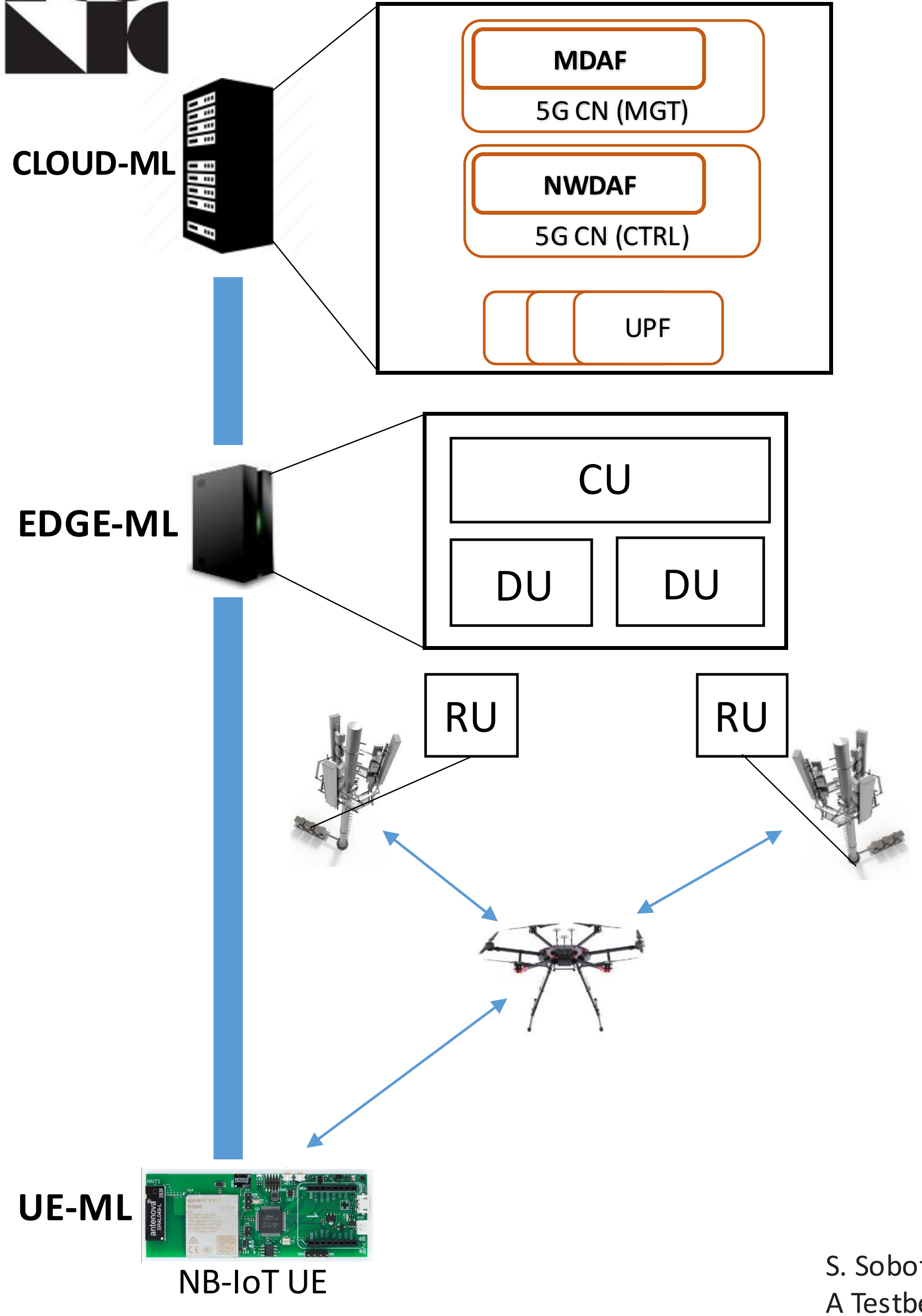
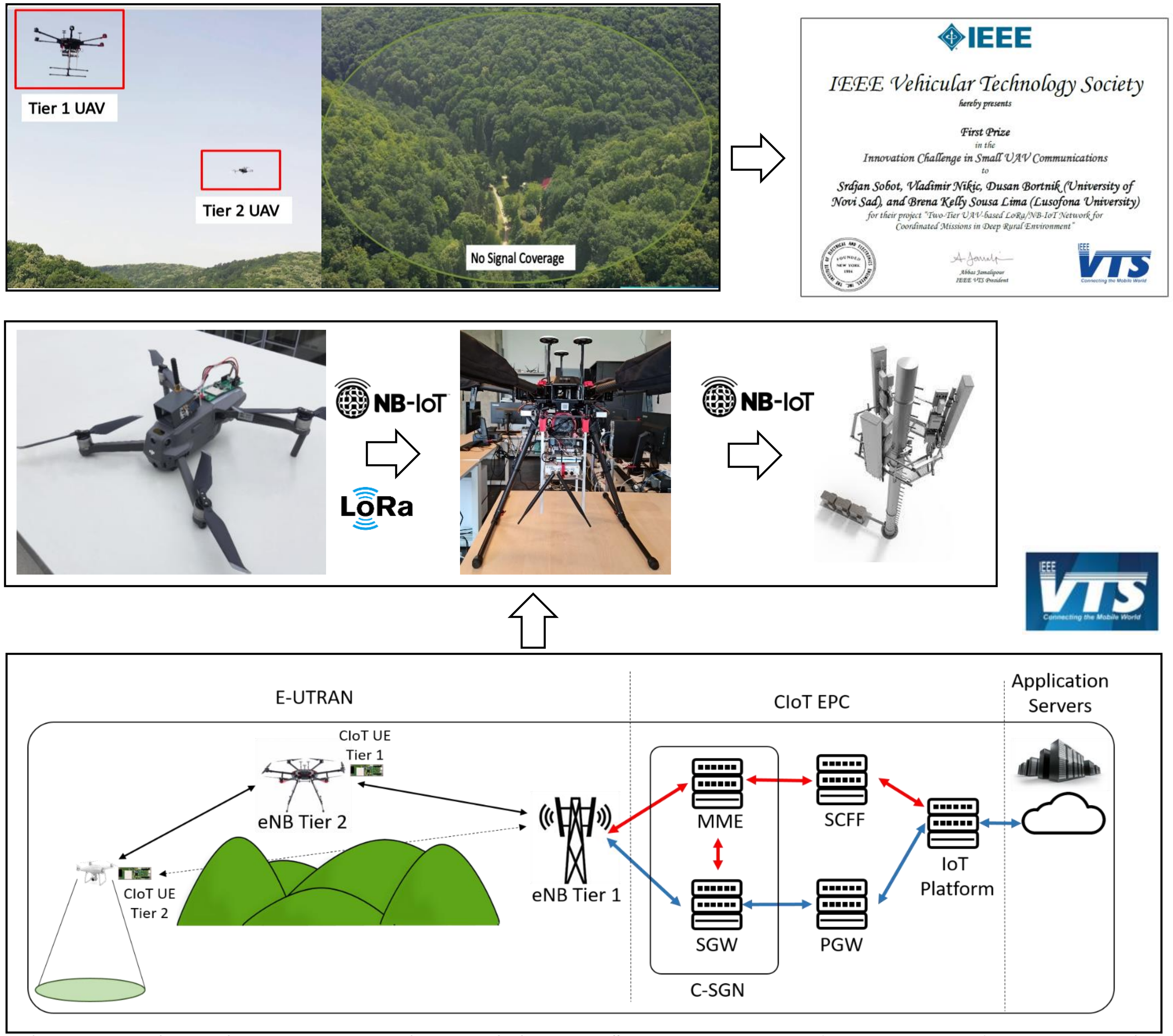


Fig. 1. Two-Tier OWC/RF-Based IoT Network.

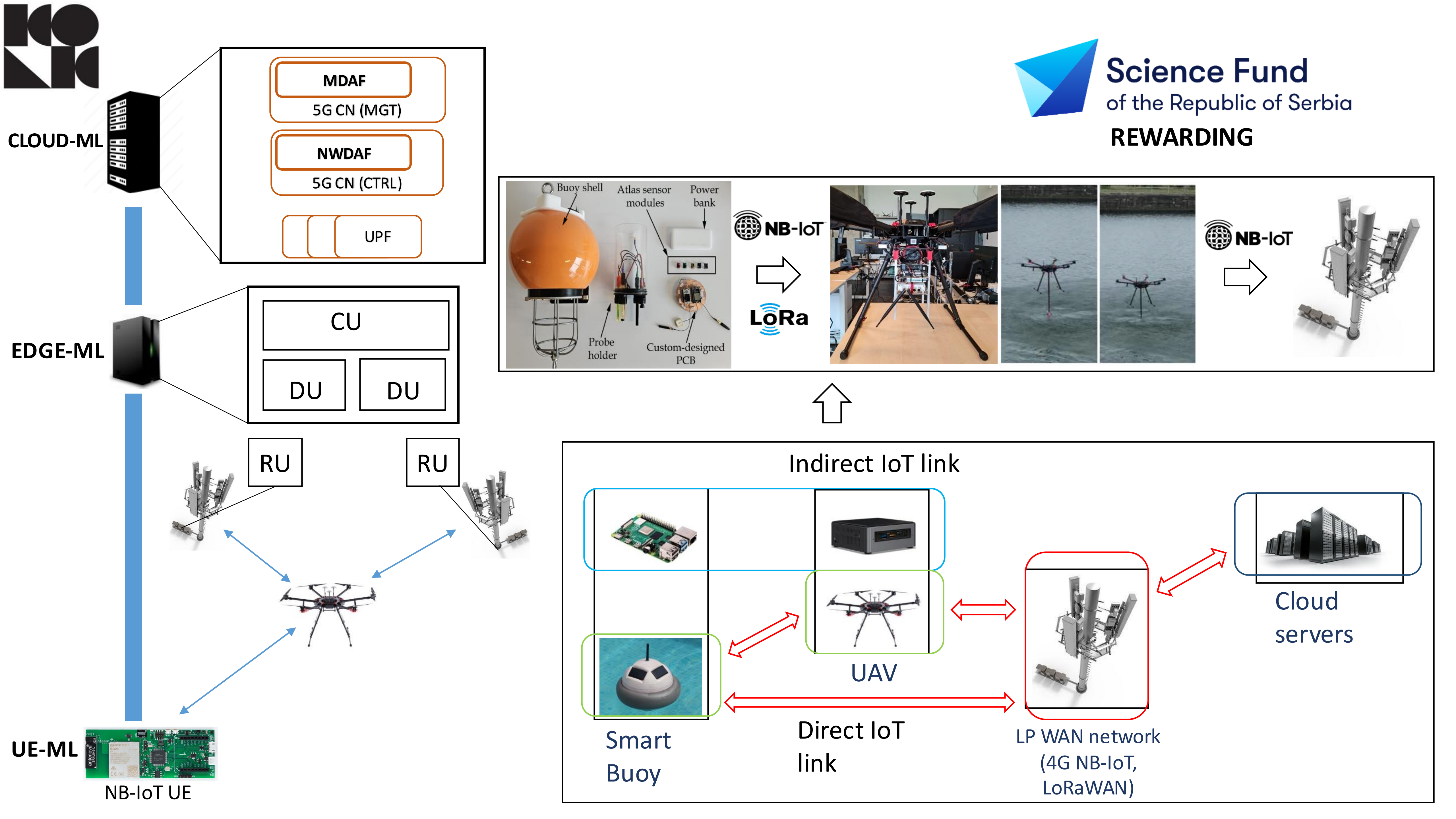
T. Devaja, M. Petkovic, F. Escribano, C. Stefanovic, D. Vukobratovic: "Slotted ALOHA with Capture for OWC-Based IoT: Finite Block-Length Performance Analysis," **IEEE Access**, Vol. 11, pp 76804-76815, 2023.

M. Petkovic, D. Vukobratovic, F. Clazzer, A. Munari, "Two-Tier Multi-Rate Slotted ALOHA for OWC/RF-Based IoT Networks," **IEEE Communication Letters**, Vol. 27, No. 4, pp. 1190-1194, April 2023.





S. Sobot, M. Lukic, D. Bortnik, V. Nikic, B. Lima, M. Beko, D. Vukobratovic: "Two-Tier UAV-Based Low Power Wide Area Networks: A Testbed and Experimentation Study," Int'l Conf on Cloud and Internet of Things CIoT 2023, Lisbon, Portugal, March 2023.


Science Fund
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NB-IoT UE
Buoy shell
Atlas sensor modules
Power bank
Probe holder
Custom-designed PCB
NB-IoT
LoRa
NB-IoT
Indirect IoT link
UAV
Smart Buoy
Direct IoT link
LP WAN network (4G NB-IoT, LoRaWAN)
Cloud servers

Environmental monitoring LP WAN testbed

Urban Environmental Monitoring Testbed

Plan: City-wide environmental monitoring testbed

Telekom Serbia C-IoT infrastructure (NB-IoT/LoRa)

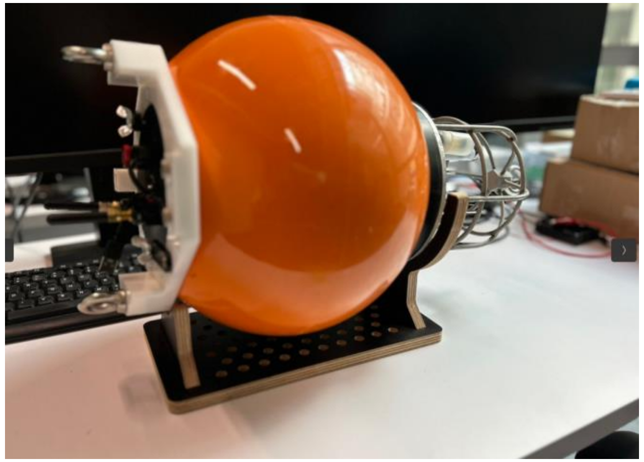
- Free-of-charge access to Telekom Serbia C-IoT infrastructure

20+ rainfall Lambrecht measurement sensors (+ THP meteo)

20+ air quality measurement sensors

Water quality measurement buoys + drone water sampling

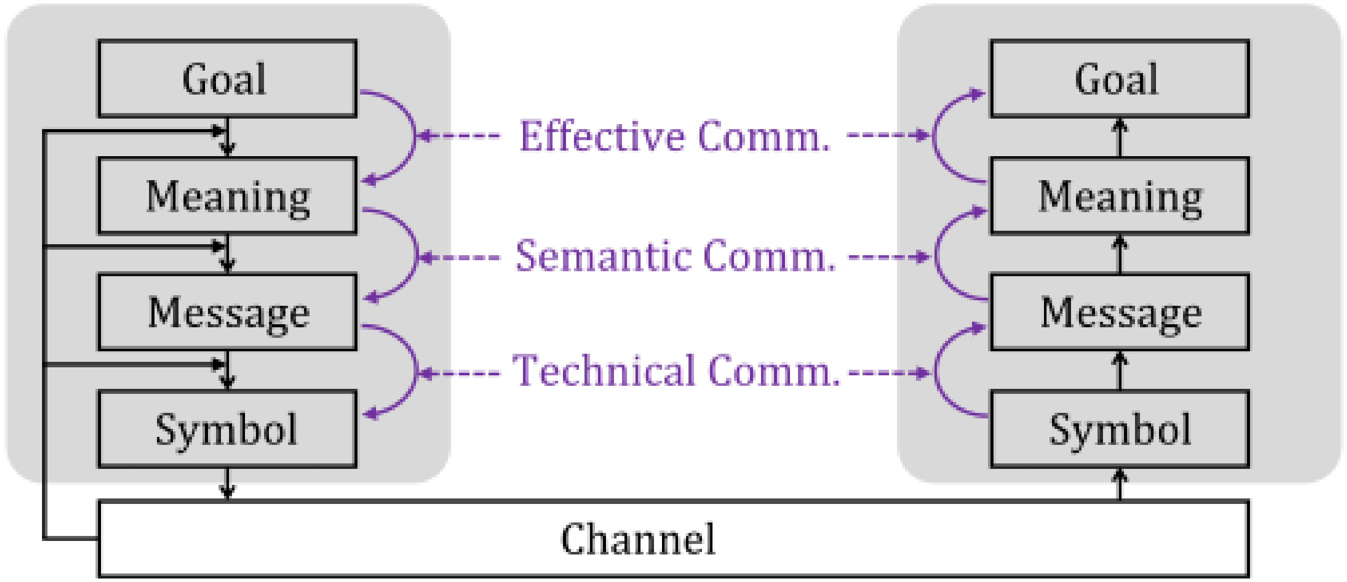
Backend infrastructure (data storage, MLOps, visualisation)



Edge ML for Massive Cellular IoT Networks

- Most of the IoT use cases deal with **time-series data**
- Data sources frequently overwhelm **limited capacity IoT data connection**
- Excessive data transfer also leads to **limited battery lifetime**
- One solution is to **offload ML model to the edge** IoT device
- **Limited edge device compute**: this may work if the model is simple
- Can we **reduce the amount of transmitted data** via data compression?
- Cost of **Compression vs Edge ML model processing**?
- Extract only relevant data for a given context: **Semantic communications**?
- Compression **aims to reconstruct source data**, SemCom does not!
- Can we design **end-to-end model** that is **optimal for a given ML task**?
- **Effective or Goal-Oriented Communications**

Goal-Oriented Communications



The effectiveness problem: How effectively does the received meaning affect desired conduct?

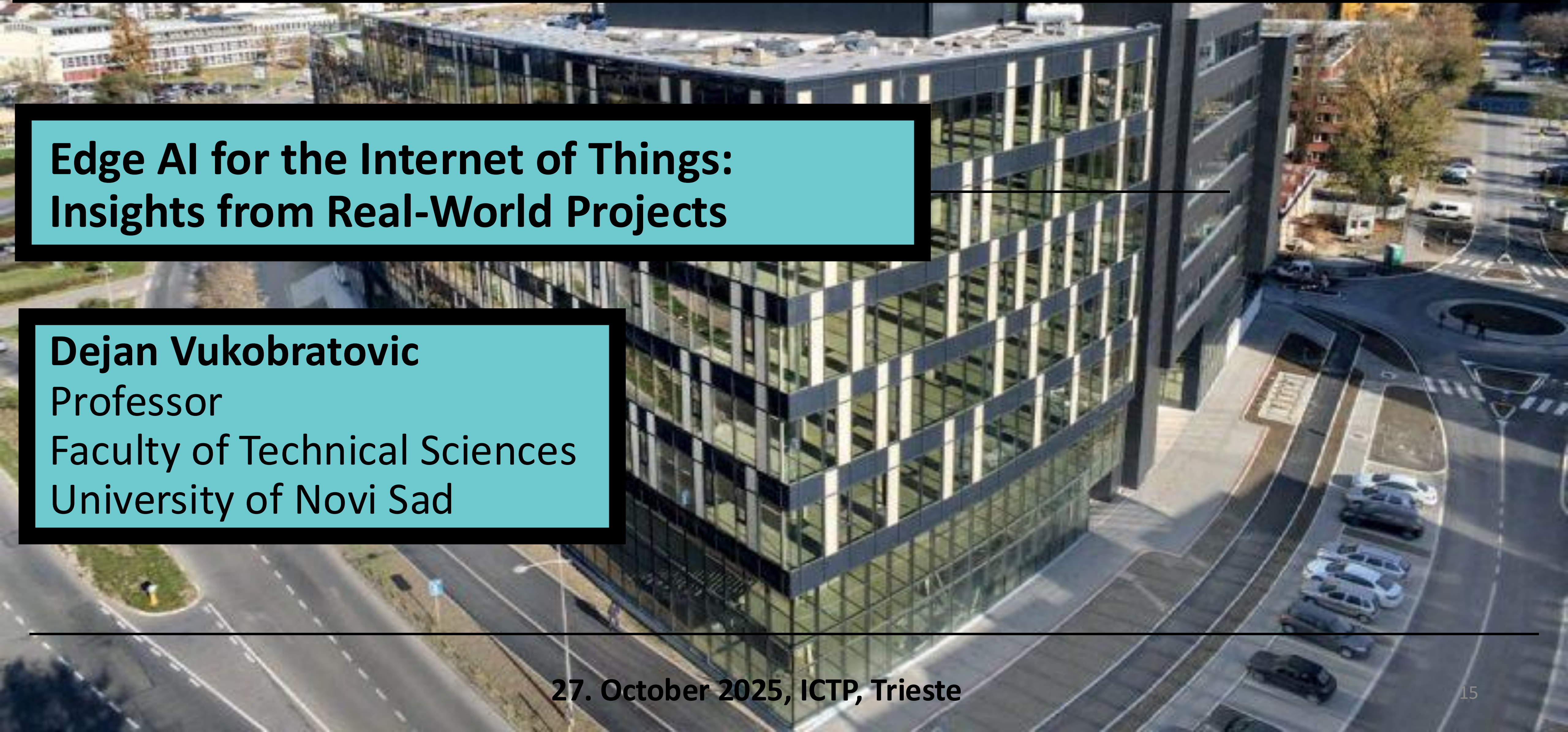
The semantic problem: How precisely do the transmitted symbols convey the desired meaning?

The technical problem: How accurately can the symbols of communication be transmitted?

Traditional Shannon-theory communications solves only the technical problem of communications.

C. E. Shannon and W. Weaver, The Mathematical Theory of Communication. Urbana, IL, USA: Univ. Illinois Press, 1949.

Y. Shao, Q. Cao, D. Gündüz, A theory of semantic communication. IEEE Transactions on Mobile Computing, 23(12), 2024.



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