EDGE AI Academy

Summer School

7-8 July 2025, Pisa, Italy

Edge AI Academy Summer School

The role IoT in edge AI

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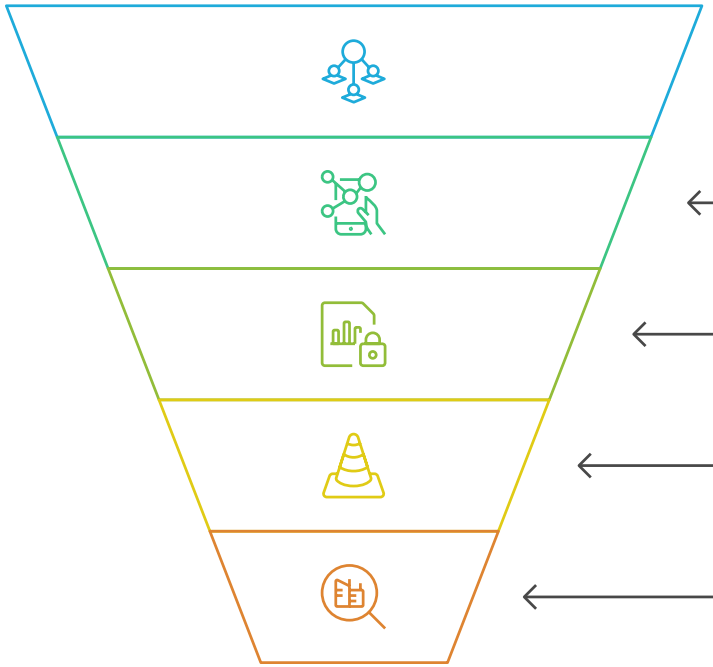
ELEKTRONIKAS UN DATORZINĀTŅU INSTITŪTS
INSTITUTE OF ELECTRONICS AND COMPUTER SCIENCE

7-8 July 2025 Pisa, Italy

Outline



Sensor networks — Exploring data collection methods

IoT architecture — Understanding foundational concepts

Security and Scalability — Addressing challenges and solutions

IoT & EdgeAI use cases — Analysing real-world applications

Future Research — Identifying emerging trends

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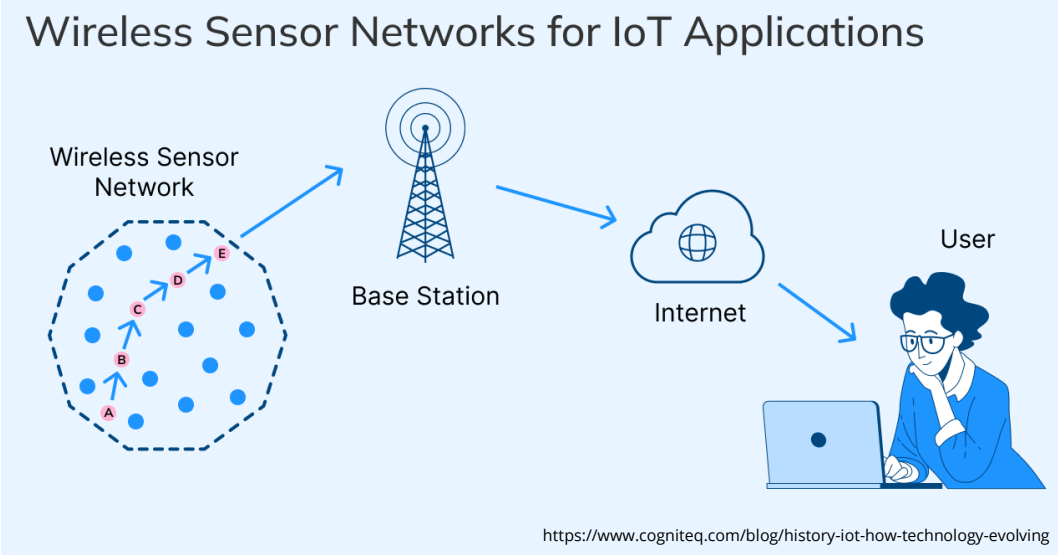
Introduction

- Wireless Sensor Network:
  - Network of physical devices collecting data
- Internet of Things:
  - User interaction and automation on top of WSN
- Edge AI:
  - Running AI models directly on edge devices, close to the source of data
  - Meta-, deep-, micro-edge
- Why This Matters:
  - Reduced latency
  - Bandwidth savings
  - Real-time intelligence
  - Decentralization



https://www.cogniteq.com/blog/history-iot-how-technology-evolving

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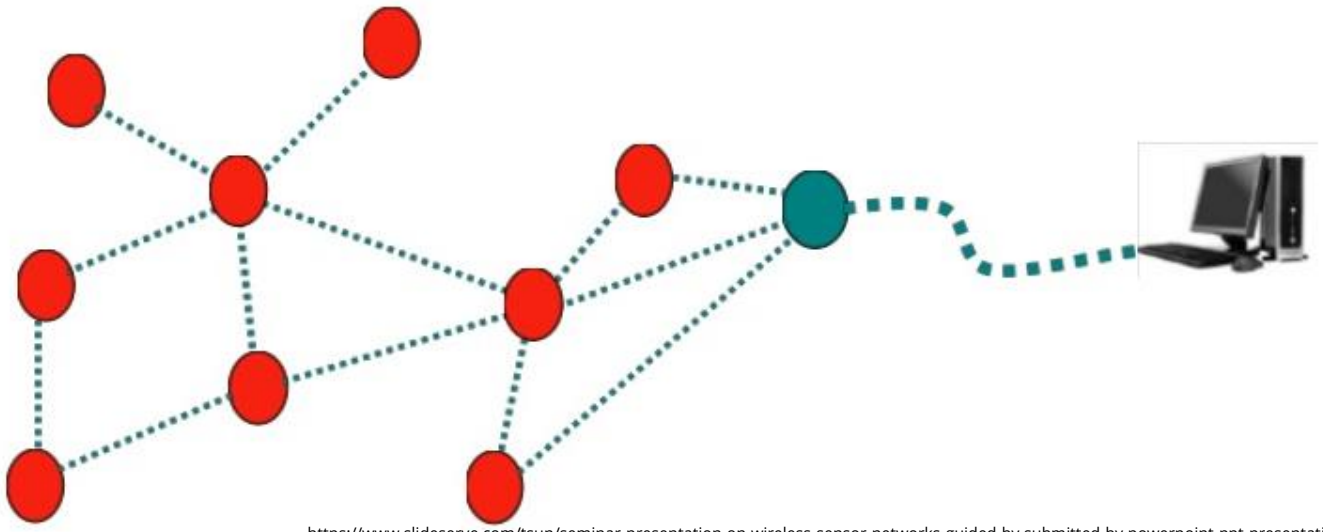
Sensor networks

- Sensors
  - Types of sensors: Vision, LIDAR, environmental, motion
  - Sensor fusion for context awareness
- Networks
  - Low-power protocols: BLE, LoRa, ZigBee, NB-IoT, IEEE 802.15.4, etc.
- Trade-offs:
  - Power consumption for battery life
    - Local processing vs transmission
  - Bandwidth for data transmission
    - Increased bandwidth costs battery life
  - Latency for real-time data
    - Decreasing delay adds complexity and costs battery life



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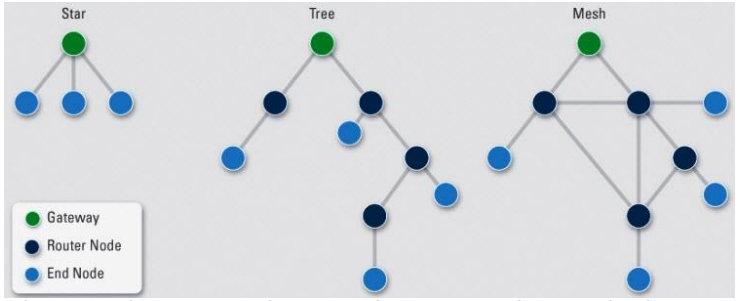
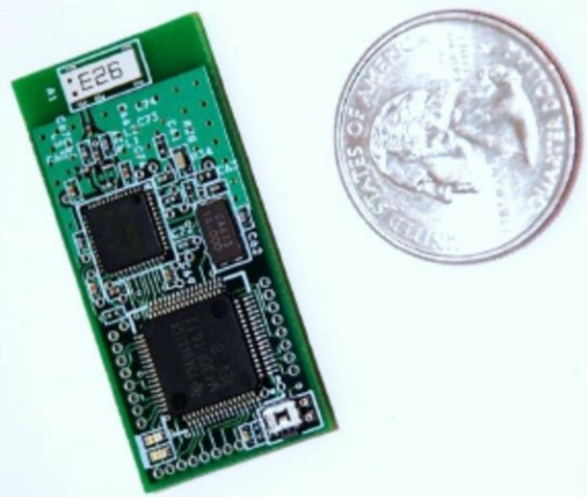


https://www.elprocus.com/introduction-to-wireless-sensor-networks-types-and-applications/



https://www.researchgate.net/figure/The-wireless-sensor-platform-with-an-MSP430-processor-and-802154-radio-for-carrying_fig1_221091606

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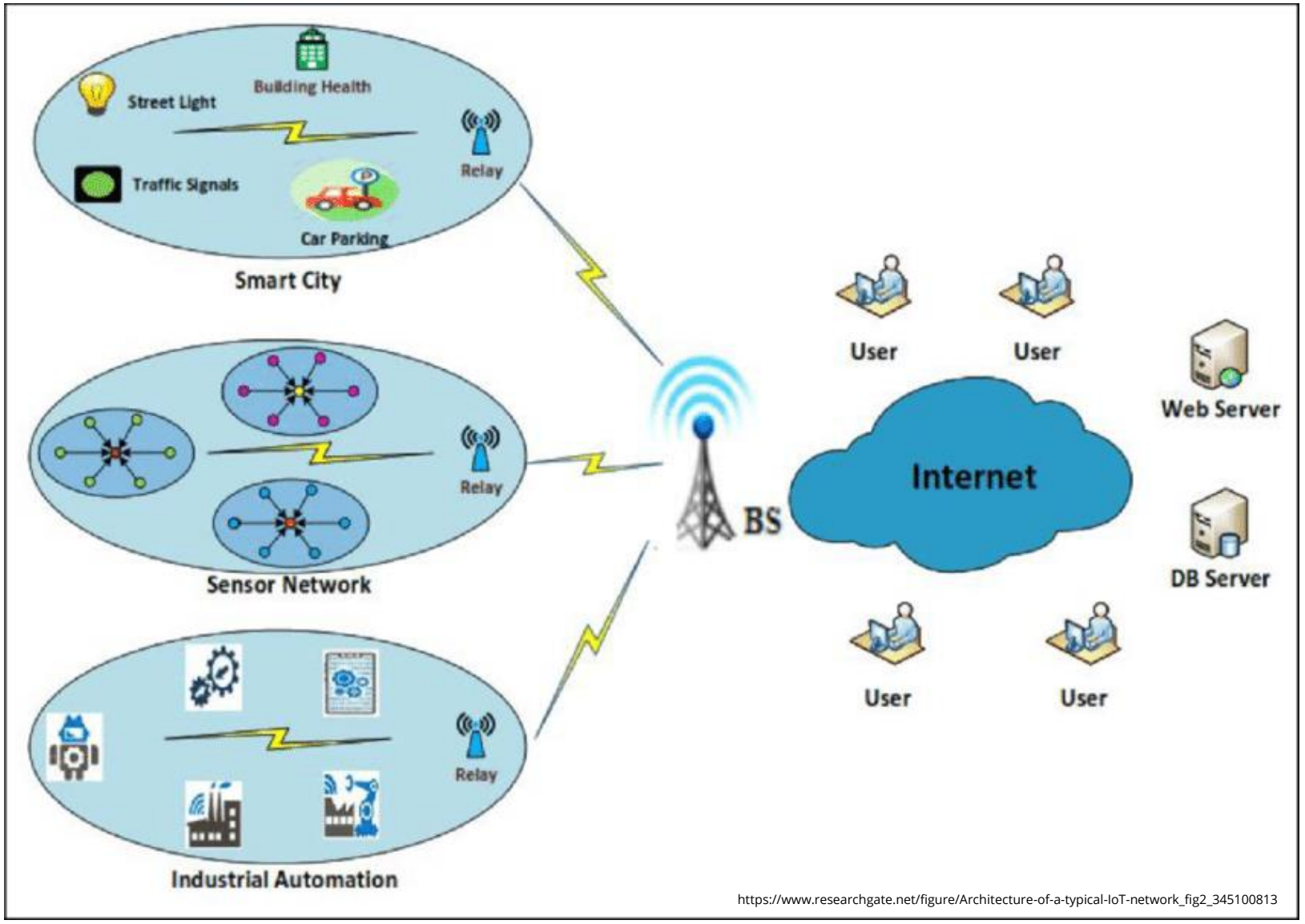
IoT architecture

- Heterogeneous
- Scattered
- Typically divided in 5 layers
  - Device layer
  - Connectivity layer
  - Platform layer
  - Application layer
  - Business layer



https://www.researchgate.net/figure/Architecture-of-a-typical-IoT-network_fig2_345100813

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Perception/Device Layer (The "Things")

Foundational layer, comprising the physical IoT devices themselves

- **Sensors:** These are the "eyes and ears" of the IoT system, collecting raw data from the physical world. Examples include temperature, humidity, pressure, motion, light, sound, GPS, etc.
- **Actuators:** These are the "hands and feet" of the IoT system. They receive commands from higher layers and perform physical actions, such as turning lights on/off, opening/closing valves, adjusting thermostats, or controlling motors
- **Identification Technologies:** RFID tags, QR codes, and other similar technologies used for identifying and tracking objects
- **Edge Devices/Microcontrollers:** The embedded hardware that houses the sensors and actuators, often with limited processing capabilities for basic data acquisition and initial processing

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Network/Connectivity Layer (The "Communication")

Responsible for secure and reliable data transmission between the perception layer and higher layers

- **Communication Networks:** Various technologies are used depending on the application's range, power, and bandwidth requirements:
  - **Short-range:** Bluetooth, Zigbee, Wi-Fi (for local connectivity)
  - **Long-range/Low-Power:** LoRaWAN, LoRa (for wide-area, low-data applications)
  - **Cellular:** 4G LTE, 5G (for high-bandwidth, wide-area applications)
  - **Wired:** Ethernet (for fixed installations)
- **Gateways:** These act as bridges between local IoT networks and the wider internet or cloud. They aggregate data from multiple devices, perform initial data filtering or protocol translation, and then forward the data upstream. Gateways can be physical devices or software components
- **Communication Protocols:** Standards that define how devices communicate, such as MQTT (Message Queuing Telemetry Transport), CoAP (Constrained Application Protocol), HTTP, and AMQP (Advanced Message Queuing Protocol)

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Data Processing/Platform Layer (The "Brain")

Focuses on managing, processing, storing, and analysing the data collected from the devices

- **Data Ingestion:** Mechanisms for securely and efficiently receiving vast amounts of data from the connectivity layer
- **Data Pre-processing/Filtering:** Cleaning, transforming, and filtering raw data to remove noise, redundancies, and prepare it for analysis. This often occurs at the edge or within specialized middleware
- **Data Storage:** Databases (SQL, NoSQL), data lakes (for raw, unstructured data), and data warehouses (for structured, processed data) are used to store the collected information
- **Real-time Analytics:** Processing and analysing data as it arrives to detect anomalies, identify trends, and trigger immediate actions
- **Big Data Analytics & Machine Learning:** Applying advanced analytical techniques and AI/ML algorithms to historical and real-time data to gain deeper insights, make predictions, and enable intelligent decision-making
- **IoT Platforms:** Cloud-based or on-premises platforms (e.g., AWS IoT Core, Azure IoT Hub, Google Cloud IoT Core) that provide services for device management, data ingestion, messaging, security, and integration with other enterprise systems

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Application Layer (The "User Interface" & "Action")

Applications that leverage the processed data to provide value to end-users and trigger actions

- **User Interfaces:** Web and mobile applications, dashboards, and visualization tools that allow users to monitor IoT devices, view data, configure settings, and receive alerts
- **Control Applications:** Software that sends commands back to actuators based on processed data or user input, automating tasks
- **Business Logic:** Defines the rules and workflows that govern the IoT system's behaviour, often integrating with existing enterprise
- **Application Programming Interfaces:** Enable seamless communication and integration between different IoT components and with external applications

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Business Layer (The "Value")

Transforming the insights derived from IoT data into tangible business value

- **Business Intelligence:** Tools and processes for analysing data to support strategic decision-making, optimize operations, and identify new revenue streams
- **Reporting & Dashboards:** Presenting key performance indicators (KPIs) and actionable insights to stakeholders
- **Process Optimization:** Using IoT data to improve efficiency, reduce costs, and enhance customer experience

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Things to keep in mind

- **Security:** Crucial at every layer, encompassing device security, data encryption, secure communication, access control, and vulnerability management
- **Scalability:** The ability of the architecture to handle a growing number of devices and increasing data volumes without compromising performance. Edge devices do have limited computational resources
- **Interoperability:** Ensuring that different devices, platforms, and systems from various manufacturers can work together seamlessly
- **Data Governance:** Policies and procedures for managing data throughout its lifecycle, including data quality, retention, and compliance

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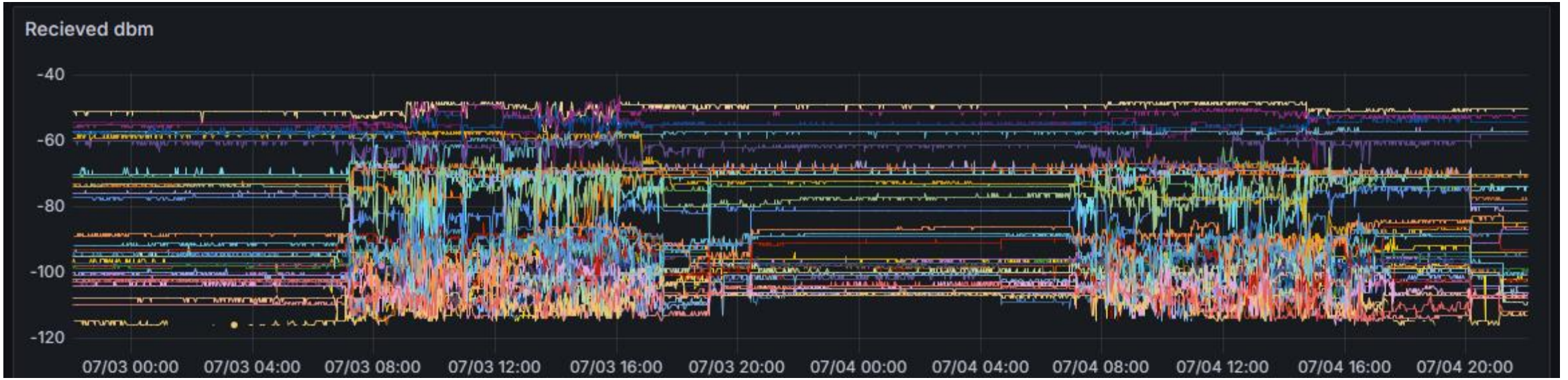
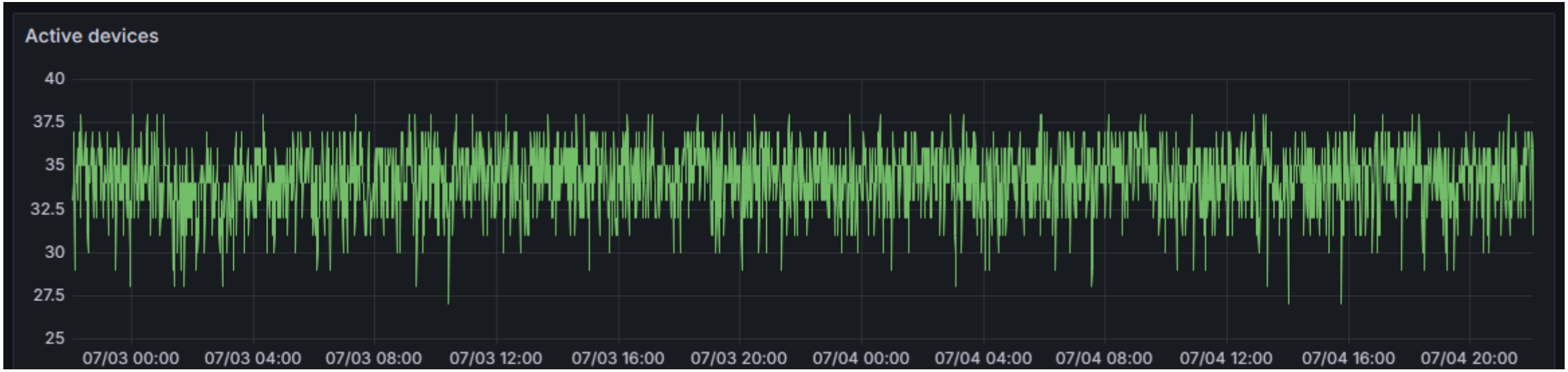
IoT data in real life





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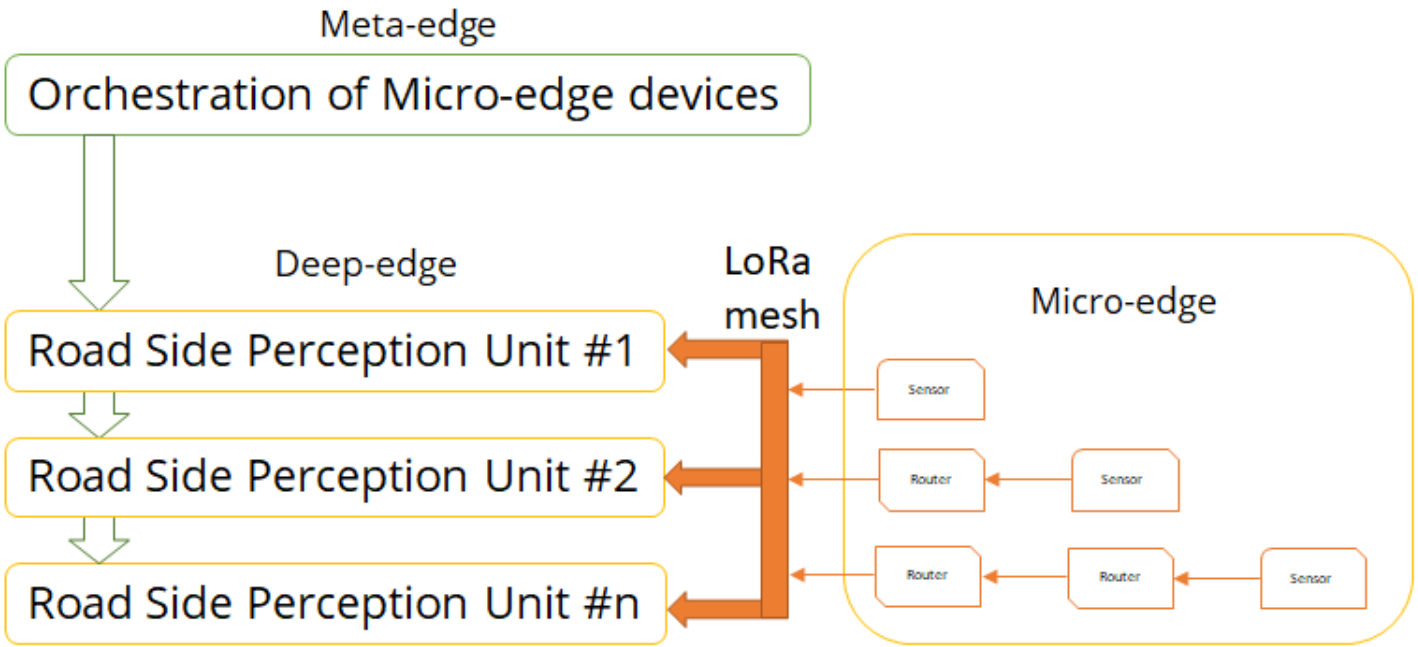
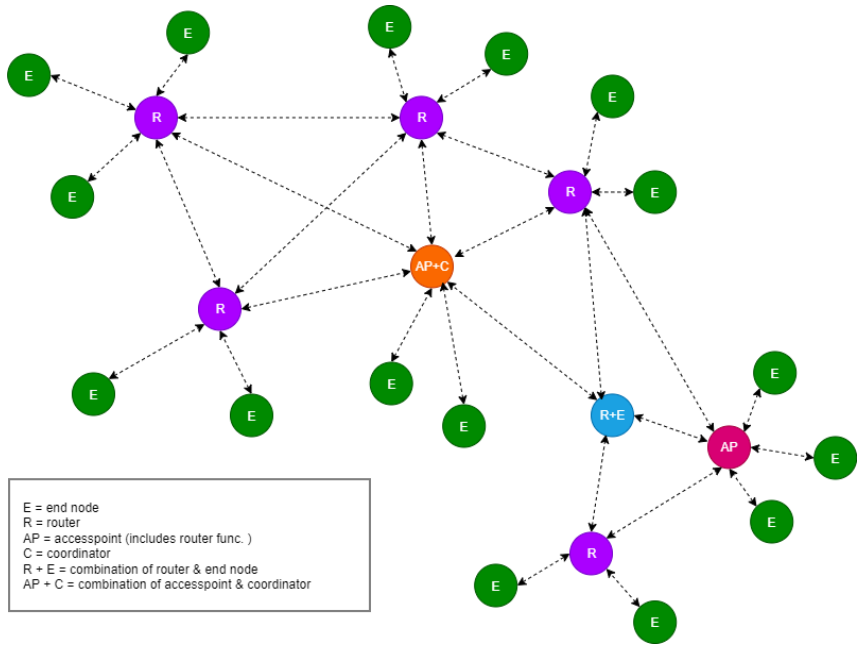
VCD4.2 : Roadside Perception Units (RSPU) connected with a LoRa 2.4 GHz mesh network

- Stationary agents interconnected by LoRa 2.4 GHz mesh network
- Modules
  - Meta-edge server
  - AI-based RSPU
  - 360-degree camera
  - Sensors: temperature, humidity, CO, CO2, O3, and SO2





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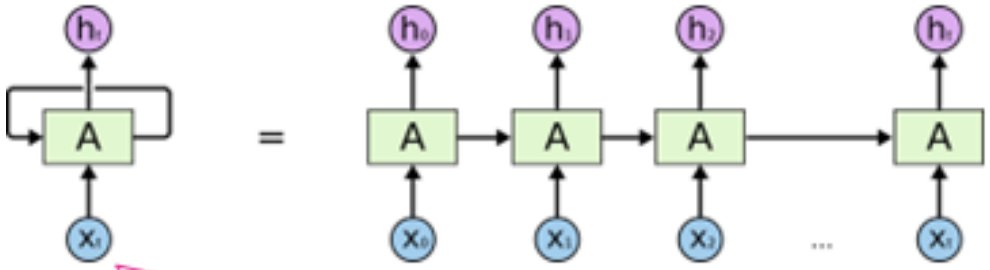
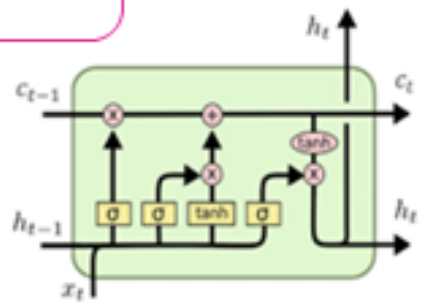
Air quality monitoring and prediction

- A holistic perspective on the air quality conditions
- Utilizing predictive AI for forecasts and analytics
- Aiming to:
  - Mitigate air pollution
  - Safeguard public health
  - Create a cleaner, safer urban environment
- Identify opportunities for improvement for service provided by the European Environment Agency (EEA).



Pollutants: O_3, NO_2, SO_2, PM10, PM25
Time: day sin, day cos, year sin, year cos
Weather: temperature, humidity



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Obstacle recognition

- Monitor the environment of an intersection
- AI obstacle detection
- Clear coverage of all possible sides of the intersection
- Recognizing obstacles as:
  - Boxes
  - Pedestrians
  - Animals
  - etc.

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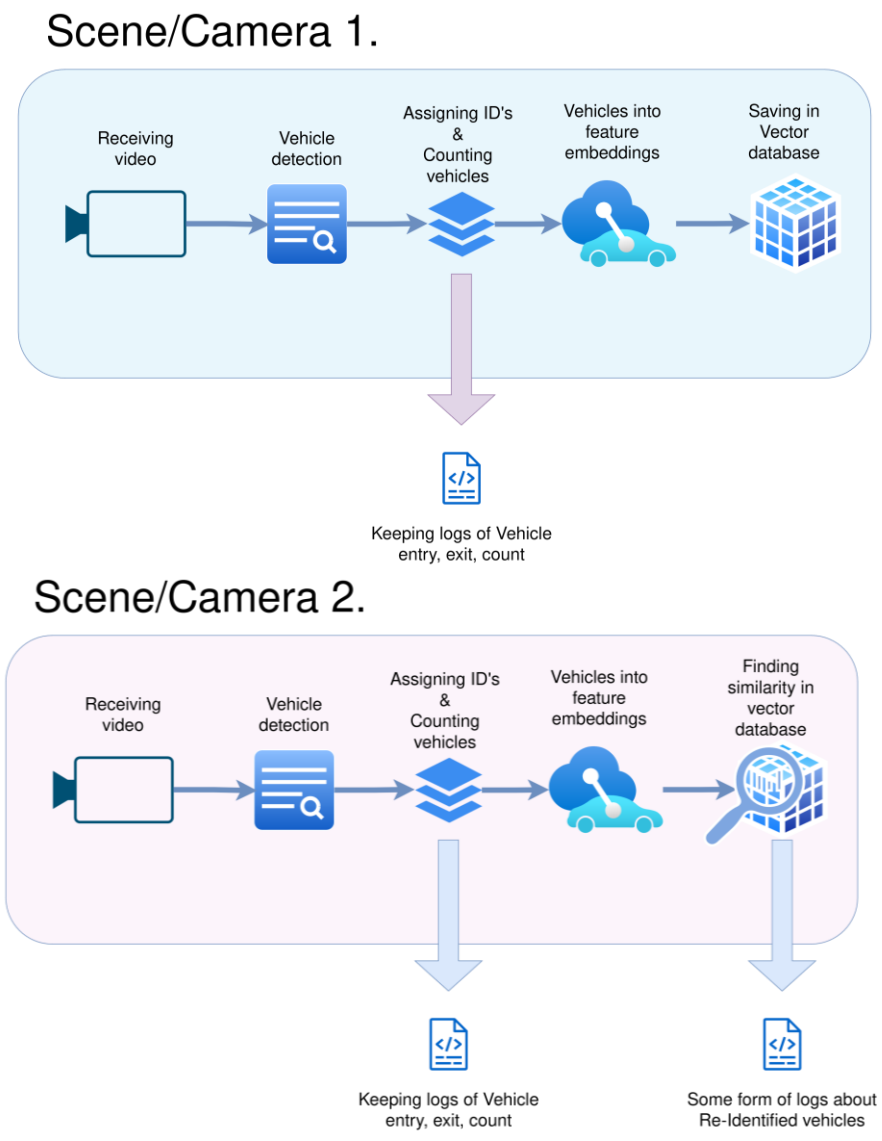
Vehicle reidentification

- Tracking vehicle movement
  - Understanding of general movement and typical routes
  - Privacy preserving approach without the identification of vehicle number plates
- Real time traffic jam information
  - Inform the users with actual situation on the roads ahead
  - Relay on data instead of user submitted information
  - Calculated information about the traffic jams can be provided to the vehicles once they enter an area covered by the LoRa mesh without the use of any cloud applications increasing the reliability and decreasing the delay.



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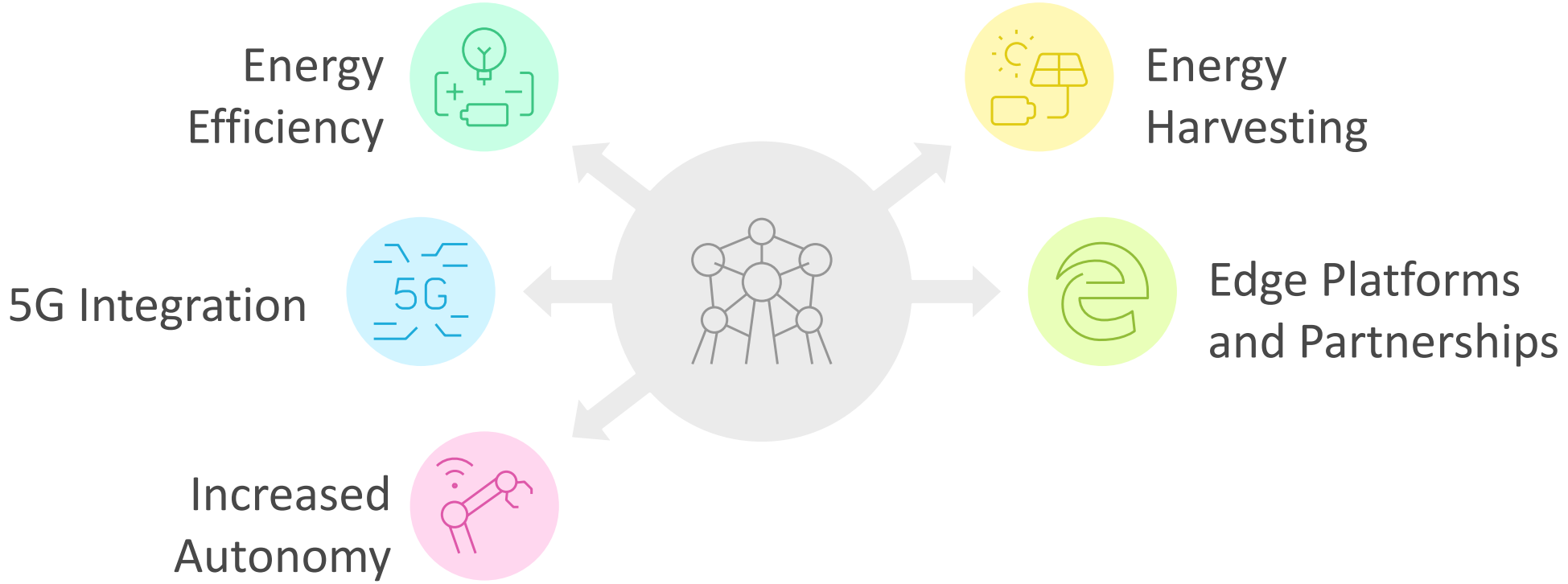
Future Research



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Conclusion

- IoT enables scalable, distributed data collection and processing
- Edge AI adds **intelligence**, **autonomy**, and **efficiency**
- Overall complexity is still very high
- Advancements in **energy efficiency**, **computing performance** and **edge AI models** will drive the innovation forwards together

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Thank You

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EAI

https://edge-ai-tech.eu/

The two-day innovative educational initiative is designed for students, young researchers, and professionals eager to expand their understanding and skills in these cutting-edge technologies.

Participants will engage in interactive discussions, hands-on sessions, and lectures covering foundational concepts and innovative applications of edge AI across various domains with leading experts, gain insights into real-world applications, and work on team-based projects to foster collaboration and innovation.

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Summer School Objectives

- The EDGE AI Academy Summer School aims to empower participants with advanced knowledge, hands-on experience and an in-depth understanding of edge AI, which combines Artificial Intelligence (AI) with edge computing and the Internet of Things (IoT) to process data closer to its source.
- Edge AI technology is gaining prominence due to its ability to enhance real-time decision-making, reduce latency, improve data privacy, and diminish reliance on continuous internet connectivity.
- The topics will extend to RISC-V architectures as ultra-low-power high-performance RISC-V-based processors and ultra-low-power vector-based accelerators are advancing smart IoT and edge AI computing capabilities.

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