A lightweight software stack and synergetic meta-orchestration framework for the next generation compute continuum

Use Case #3: Energy management in smart buildings/cities

Rafael Marin – Odin Solutions S.L.
Alejandro Arias – Odin Solutions S.L.
Use Case #3: Energy management in smart buildings/cities

**Partners:** ODINS (support of SIEMENS and IBM)

**Duration:** M16 – M36 i.e. January 2024 – September 2025

**Description:** development & evaluation of NEPHELE technologies for **intelligent monitoring and remote energy management** in a testbed scenario of smart building provided by ODINS in Murcia,

**Objectives:**
- To develop applications to allow **energy efficient control** actions of building equipment.
- To offer customized services to end-users to improve energy-efficient and well-being.
- To provide an automation scheme based on **real-time information and video/image processing** from different IoT devices and Edge nodes.

**Nephele integration:** The smart energy services will be:
- Implemented with VOStack in Edge nodes by the integrated meta-orchestration framework.

**Technical challenges:**
- **Data security** is of paramount importance for smart building applications, especially when end users’ data form part of the decision processes.
- **Real-time or almost real-time** execution of data analysis for complex event decisions.
## NEPHELE Use Cases

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Use Case #3: Energy management in smart buildings/cities

This use case will provide several applications and services:

I. **Distributed complex decision making**, where VOs Edge nodes will perform **intelligent energy saving actions** not only based on the sensor measures collected by the IoT devices managed, but also the information and data coming from other nodes. This will drive the efficient use of renewable energy sources and the reduction of peaks in the energy consumption.

II. **Distributed authorization scenarios** where an access request to a resource is not decided exclusively by a centralized cloud platform but made by a back-end service leveraging in a Distributed Ledger Technology (DLT), that stores distributed access control policies, (e.g., distributed-XACML), employed at the edge nodes closest to the target resource to enforce access.

III. **Object/Person detection through AI-assisted image processing** tasks running in distributed Edge nodes. This is achieved from the data collected by video cameras deployed in the scenario for finding dangerous or suspicious objects, and getting the location of vulnerable persons, such as missing children or lost elders.
Use Case #3: Energy management in smart buildings/cities

This use case will implement several applications:

IV. **Communication radio offloading** for battery-powered devices or subscription base technologies. Decentralized AI-assisted orchestration of VOs may avoid certain radio channels to save either IoT device battery or subscriber data, by offloading the communication flows to auxiliary technologies (e.g., switching from NB-IoT to WiFi access point).

V. **Customization IoT devices to support energy-efficiency and well-being in buildings**. As extension of case II, this application will demonstrate how the true presence in rooms can be easily determined and how that information can be used to make a Building Automation Systems (BAS) more energy efficient.
Use Case #3: Stakeholders, locations and constrains

**Stakeholders:** all parties participating or affected by the use case

**Constrains, challenges & risks:**
- reliability of the network
- trust
- privacy risk
- constrained IoT devices
- regulatory limitations
- real-time execution

**Location** of the use case, physical or virtual (as specific as possible)
- cloud
- buildings
- urban furniture
- appliances
- cameras
- sensors
- smartphones
- network infrastructure
- user data security
- network operators
- edge
- gateways
- IoT device manufactures
- HVAC manufacturers & installers
- businesses and companies
- ministry of economy, transport & industry
- energy providers
- energy communities
- architects & builders
- appliance manufacturers
- citizens
- city government
- economic risks
- heterogeneous devices
Use Case #3: Stakeholders, locations and constrains

Stakeholders
Citizens, Local government, Building managers and energy communities, and security services

Locations
Buildings, urban furniture, lighting systems, traffic lights, IoT devices, HVAC systems, …

Constrains
Advanced data analysis, privacy preserving of the dataset, regulatory limitations

Challenges
Real time data, security of communication, privacy, network connectivity, support heterogeneous devices, provide user-friendly interfaces to simplify the interaction with VOs and applications

Risks
Privacy and economic risks
Use Case #3: Energy management in smart buildings/cities

This use case will collect the following functionalities:

- Software component orchestration
- Device customization and management
- Device interoperability standardized interfaces
- Access control management
- Identity management (issuers and verifiers)
- Data storage service
  - Secure
  - Decentralized
- Low latency communication
- Computer vision for information extraction
- Intelligent data filtering/aggregation/compression
Use Case #3: Energy management in smart buildings/cities
Application Scenario: DID and Verifiable Credentials
Application Scenario: DID and Verifiable Credentials (II)
Application Scenario: DID and Verifiable Credentials (III)
Application Scenario: Distributed complex decision making (I)
Application Scenario: Distributed complex decision making (II)
Application Scenario: Distributed Access Control (I)
Application Scenario: Distributed Access Control (II)
Application Scenario: Distributed Access Control (III/III)
Application Scenario: Object/person detection through IA-assisted image processing (I)
Application Scenario: Object/person detection through IA-assisted image processing (II)
Application Scenario: Communication radio offloading (I)
Application Scenario: Communication radio offloading (II)
Application Scenario: Customizable IoT devices to support energy-efficient and well-being in buildings (I)
Application Scenario: Customizable IoT devices to support energy-efficient and well-being in buildings (II)
Use Case #3: Energy management in smart buildings/cities

**Testbed: PEANA** - Enhanced Platform for IoT Smart Cities and Buildings

- Temperature
- Humidity
- Light
- Air Quality Sensors (CO2)
- Occupancy detection
- Smart Sockets
  - Energy consumption
  - Automated management

- Mechanical ventilation
- Temperatures at all stages
- Pressure differences
- Monitoring of power consumption
- Actuation
Use Case #3: Energy management in smart buildings/cities

Equipment:
The existing IoT and Edge/Cloud computing infrastructure is mainly composed by wireless microcontroller IoT devices communicating with Edge nodes and cloud platforms.

The IoT constrained devices include:
- sensors: temperature, humidity, CO2, power meters, cameras
- actuators to control different environment parameters
  - Smart plugs, HVACs, network controllers, ...

Used IoT constrained devices communication with edge nodes:
- Protocols: REST, COAP
- Wireless radio technologies: Wifi or NB-IoT.
Use Case #3: Devices at physical, networking and computation levels

- **IoT Connector**
  - Connectivity: 5G, WiFi, Bluetooth, Zigbee
  - Computation: base on Raspberry Pi 4

- **Physical**
  - Wi-Fi / Zigbee / RF

- **Networking**
  - 5G

- **Computation**
  - Edge Server
  - Cloud

- **Wireless sensors and actuators**
Use Case #3: Virtual Object mapping
Thank you!
1. Dynamic Virtual Functions with Kubernetes NFV
2. Translating communication protocols, security, semantic & data models
Use case of Energy Management in Smart Buildings

HORIZON call: HORIZON-CL4-2021-DATA-01-05 (RIA); Project NEPHELE 101070487; Period: 01-09-2022 to 31-08-2025; EC contribution 9 mill. EUR.

**Concept:**
Development & evaluation of NEPHELE technologies (Virtual Objects and Virtual Object Stack) for intelligent monitoring and remote energy management in the continuum in the context of smart buildings. The objectives are developing applications to allow energy-efficient control actions, offering customized services to end-users and providing automation schema based on real-time information. The use case is also focus on video analysis for person and object detection.

**Benefits:**
Real-time monitoring and data processing using AI models for decision making and control automation thanks to the aggregation of data from different sources. The use of virtual objects allows adding to constrained IoT devices, advanced computing capabilities that allow complex cryptography, advanced security systems, better management of device and network resources, improving performance and savings energy, while offering broader and more intelligent control of the energy management systems.
Synergetic Orchestration Mechanisms

Synergetic Cloud/Edge Computing Meta-Orchestrator

- High Level Goals
  - Energy Efficiency
  - Cost Reduction
  - High Performance
  - Data Privacy
- End-to-end Orchestration in the Compute Continuum (System of Systems)
- Machine Learning Workflows

Hyper-distributed Applications Repository
- Application Graphs
- Virtual Objects
  - Generic Functions

Federated Resources Manager
- Global Resources Management
- Optimisation Engine
- Elasticity, Live Migration
  - Trust Management
  - Edge Computing Cluster Manager
  - Cloud Computing Cluster Manager

Compute Continuum Network Manager
- Network Slice Management (network isolation, security)
- Network Services Orchestration (SDN, NFV)
- QoS Assurance, SLAs Management
- Distributed Monitoring
Use Case #3: Virtual Object mapping
Summary of the contributions (6/6)