



Data integration & interoperability:

Data integration & Data modeling with other sources/software

Panagiotis Klonis, CERTH

CERTH SmartWins Summer School: Day 3

06 July 2023

Thessaloniki

❖ Data Integration and Interoperability

- Enabling Seamless Data Exchange
- Efficient data sharing towards more efficient decision-making
- Eliminating data silos and promote collaboration
- Enhancing data accuracy and consistency

❖ Data Integration

- **The process of combining data from multiple sources to provide a unified view**
 1. Extraction: Gathering data from different systems and sources
 2. Transformation: Conversion and harmonization of data to a common format
 3. Loading: Storing the integrated data in a central repository
- **Challenges**
 1. Data incompatibility(different formats, schemas, etc.)
 2. Data quality issues(duplication, errors, proper validation)
 3. Security and privacy considerations

❖ Data Interoperability

- The ability of systems and applications to communicate and exchange data seamlessly
- Use of standardized data formats and protocols
- Use of Defined Interfaces and APIs
- Enhancement of Compatibility across different platforms and technologies
- Facilitation of integration and collaboration among diverse systems
- Scalability and Extensibility

❖ **Data Importance of Software Design Architecture**

- Provides a blueprint for organizing and structuring systems and data
- Defines components, modules and interactions
- Enables scalability, flexibility and maintainability

❖ **Principles of a robust architecture design**

- Modular design: Breaking down the system into independent modules
- Minimizing dependencies between components
- Scalability: Handling growing data volumes
- Flexibility: Adapting to changes in requirements and technologies

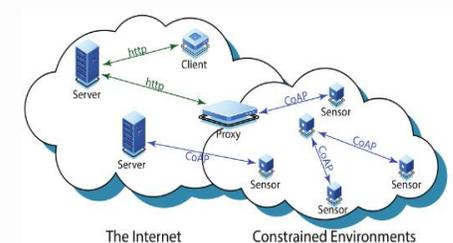
Data integration & interoperability

❖ Data Transmission protocols for IoT devices

- A set of rules/standards that govern data exchanging among IoT devices and systems
- Define format, structure and procedures of data transmission
- Facilitate IoT systems optimal functionality, real-time monitoring, control and decision making

❖ Most Commonly Used Protocols

- **MQTT:**
 - Lightweight publish-subscribe model efficient for one-to-many communication
 - Low latency, power consumption
 - *QoS – Quality of Service* levels for reliable message delivery
- **CoAP:**
 - Lightweight with built-in resource discovery and caching mechanisms
 - Request-Response support functionality and asynchronous notifications
 - Reliable or Best-Effort message delivery features
- **HTTP:**
 - Well-established, extensive support and compatibility
 - Rich methods for data manipulation(GET, POST, PUT, DELETE)
 - Preferred for web-based services and APIs
- **XMPP:**
 - Designed for instant messaging
 - Extended for IoT communication, device control, sensor data collection, event notifications
 - Can be integrated with other protocols like HTTP and MQTT



Data integration & interoperability

❖ Devices Connections Architecture

- Ways devices are interconnected in a network
- Ways to communicate with each other

❖ Most Commonly Used

➤ Star Architecture:

- Centralized design with a single hub or gateway for device connection
- Devices communication directly with hub, not with each other
- Home automation

➤ Mesh Architecture:

- Decentralized design, devices communicate directly
- Data routed through multiple paths, no single point of failure
- Increased complexity in managing network routing
- Smart city where devices need to communicate across a large area

➤ Tree architecture:

- Efficient for hierarchical systems
- Reduced communication overhead
- Industrial monitoring systems(factory automation)

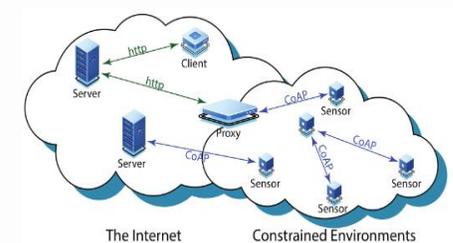
Data integration & interoperability

❖ Communication with Gateways

- Interaction and data exchange between devices or networks and a gateway device
- Gateway acts as a bridge between different networks, protocols, e.t.c.
- Facilitate communication interoperability

❖ Important functionality

- Network interconnection
- Protocol conversion
- Security and Firewall
- Data Aggregation and Processing
- Remote Management and Control
- Interaction with Cloud Services
- Interoperability and Standardization



Data integration & interoperability

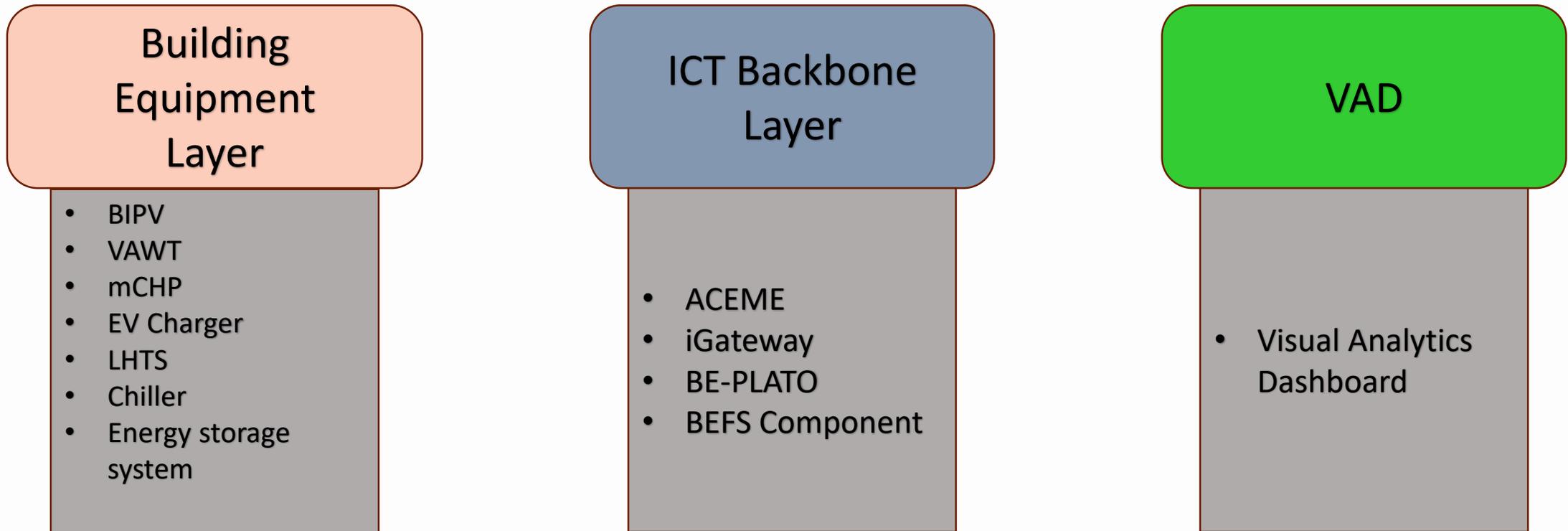
❖ RE-COGNITION PROJECT



- **Develop a solution aiming to:**
 - Maximize utilization of locally produced energy by building level renewable energy technologies
 - Reduce implicitly and explicitly induced costs towards Zero Energy Building's realization
- **Cross-Functional Renewable Energy Sources Integration Platform**
 - Automated Cognitive Energy Management Engine (ACEME)
 - BuildingEnergy Plant Planning Tool (BE-PLATO)
 - iGateway
 - Visual Analytics Dashboard
- **Technologies Used**



❖ RE-COGNITION PROJECT – Conceptual architecture



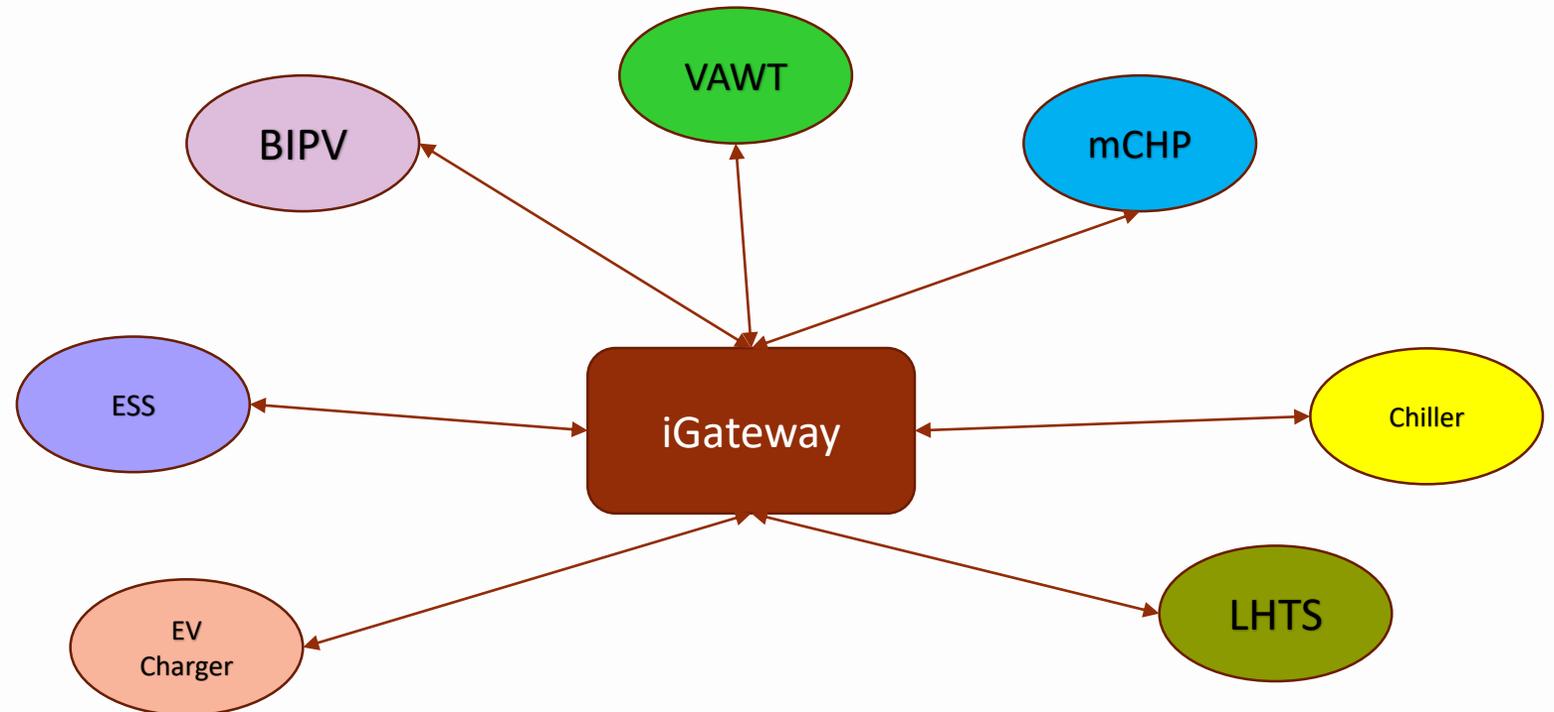
Data integration & interoperability

❖ RE-COGNITION PROJECT – Devices Connections architecture



➤ Star Architecture

- Centralized Design
- iGateway for connection



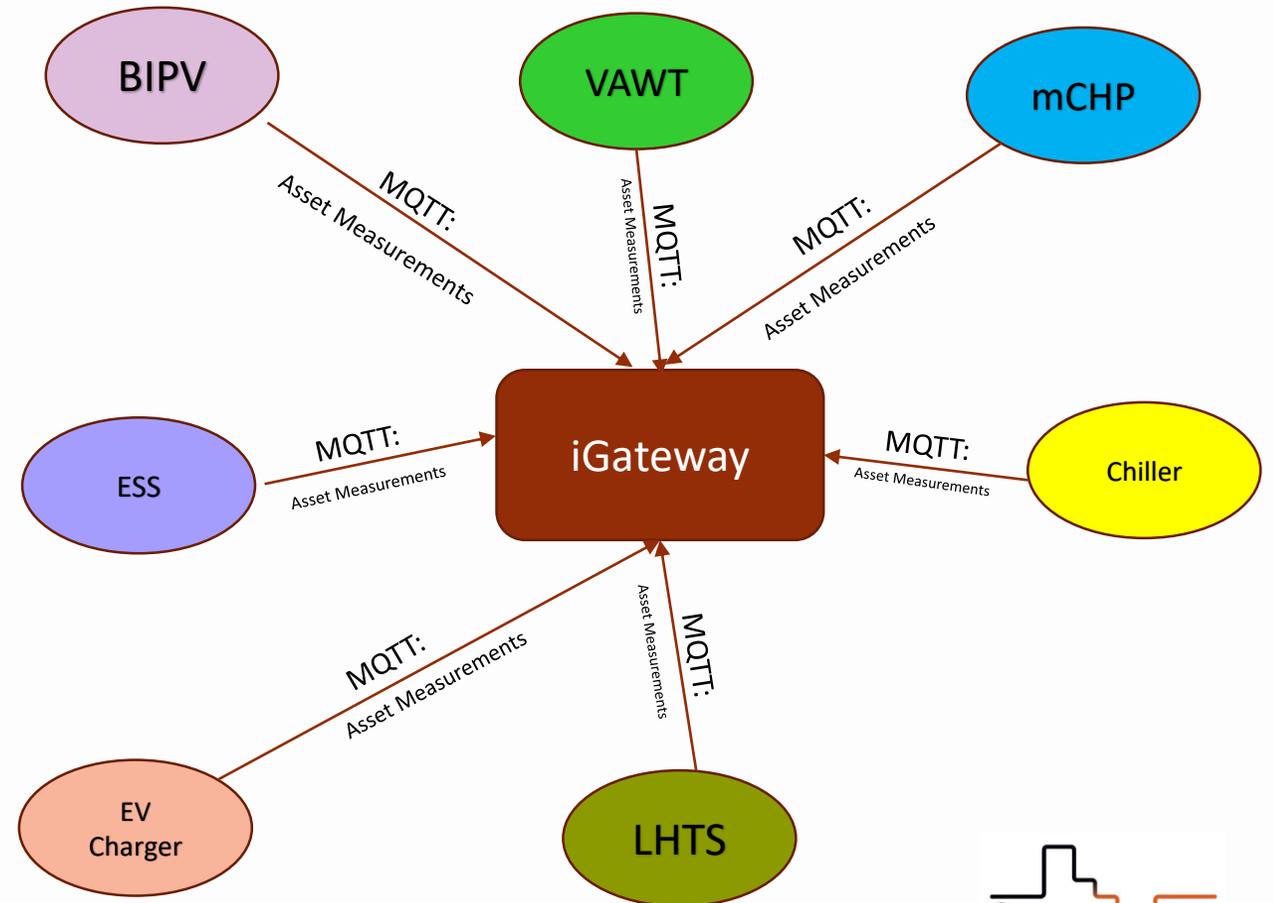
Data integration & interoperability

❖ RE-COGNITION PROJECT – iGateway(1)



➤ iGateway

- Based on NODE-RED configuration environment
- Modular, Scalable
- Standardize protocols (wired/wireless)
- Configures and handles data flows
- Communication with ACEME component
- Device discovery in the network
- Data storage capability
- Data Processing Module
- Real-Time Local Engine
- Hardware: Raspberry Pi 4



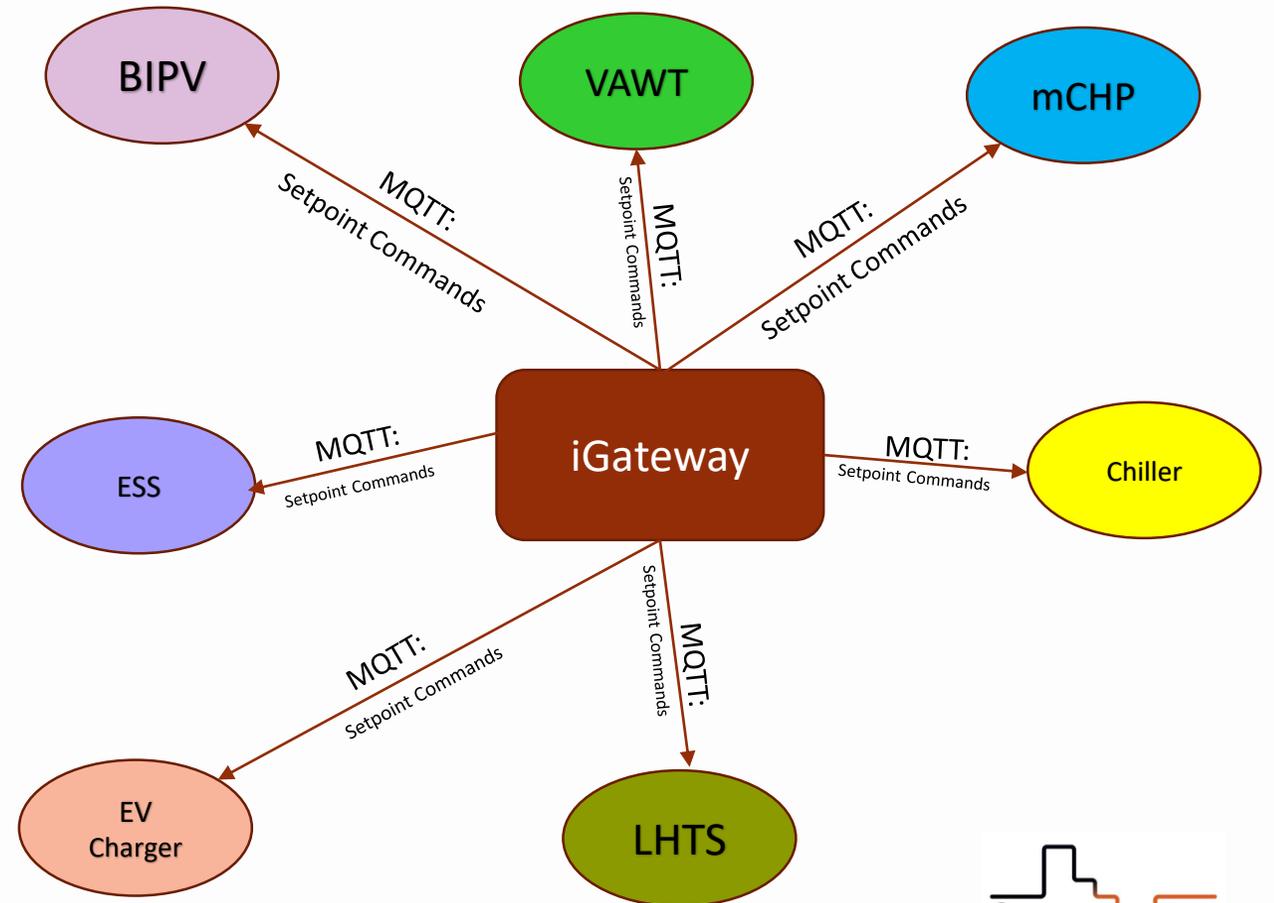
Data integration & interoperability

❖ RE-COGNITION PROJECT – iGateway(2)



➤ iGateway

- Based on NODE-RED configuration environment
- Modular, Scalable
- Standardize protocols (wired/wireless)
- Configures and handles data flows
- Communication with ACME component
- Device discovery in the network
- Data storage capability
- Data Processing Module
- Real-Time Local Engine
- Hardware: Raspberry Pi 4



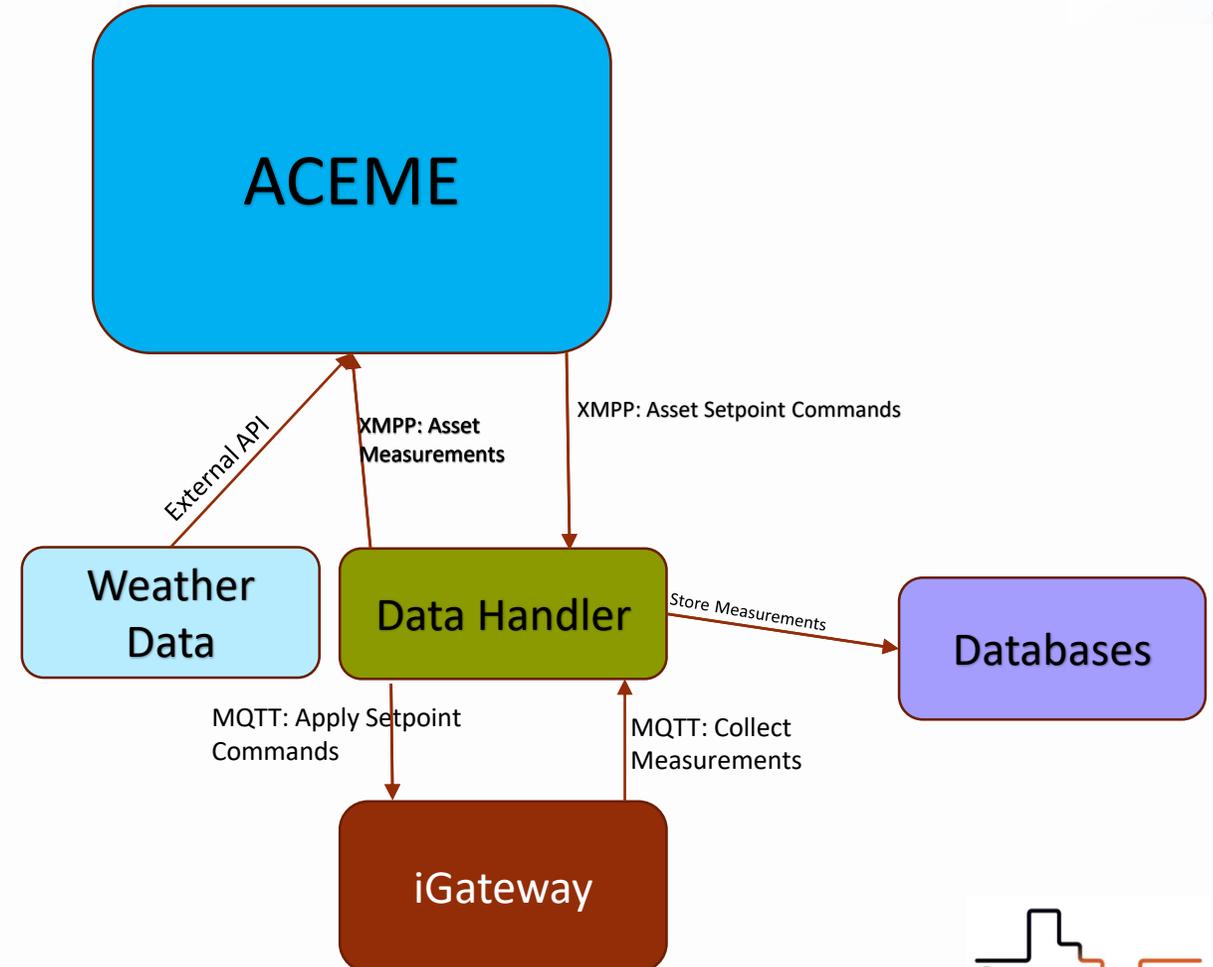
Data integration & interoperability

❖ RE-COGNITION PROJECT – ICT Backbone layer



➤ ACEME – Automated Cognitive Energy Management Engine

- Main Goal: Achieve highest possible level of RES penetration through a decision making system
- Receives data from on-site energy consuming devices
- Predicts patterns regarding the aggregated load per building
- Distributes intelligence via an agent –based representation of each energy Asset

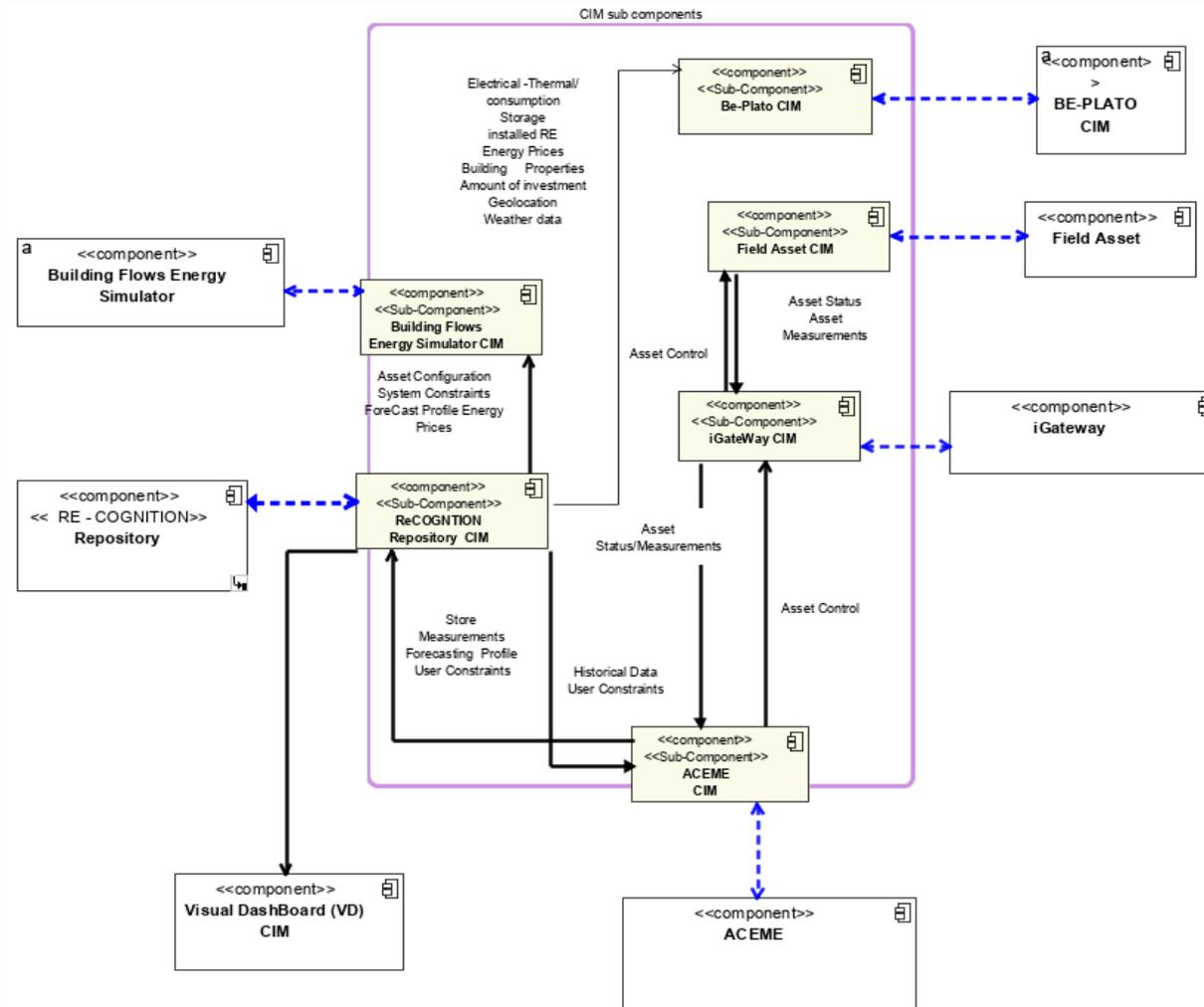


❖ **RE-COGNITION Common Information Model (CIM)**

- Responsible for transparent data exchange among architecture components
- Implements several CIM sub-components to assist deployment of RE-COGNITION main components
- Ensures data interoperability by having an interface for each CIM sub-component
- Depicts different components interrelations

Data integration & interoperability

❖ RE-COGNITION CIM - high level view



❖ RE-COGNITION CIM designed to:

- Facilitate translation of different formats into a common understandable format
- Describe sources of information in a common terminology to all RE-COGNITION components
- Standardize a format acceptable by all project partners when proceeding “from specification to implementation” regarding project tasks

❖ Methodology

1. Analysis of relevant approaches and standards
2. Analysis of RE-COGNITION data requirements based on architecture components and functionalities

❖ RE-COGNITION CIM – Final Version(1)

1. Data Modeling:

a) Use of Ontology concept to:

- i. Create entities hierarchy providing important information semantically-wise
- ii. Clarify entities linkage and interrelations
- iii. Identify best practice for data storing and creating the CIM data repository

b) Data models in JSON_LD format

- i. Ideal to create well wrapped payloads of linked data and facilitate data exchange
- ii. Ensure data communication in common format and validation
- iii. Facilitate data storing

❖ RE-COGNITION CIM – Data Modelling(1)

❖ Ontology

- Data modelling concept
- Ideal for RDF data
 - A standard for data interchange on the web
 - Flexible, extendable
- Hierarchical design - Organize data models in classes
- Predefine data linkage and interrelation in class level
- Allow direct linkage for class instances
- Saved in owl format
 - Practically a logic-based language exploitable by computer programs
- Other formats
 - turtle
 - RDF-XML
- Entities defined in the web by URIs as downloadable resources
- Data saved as triples – *RDF Triplestore*
- *SPARQL queries*

❖ RE-COGNITION CIM – Data Modelling(2)

The screenshot displays the Protégé ontology editor interface for the 'ontology' project. The left pane shows a class hierarchy starting with 'owl:Thing', which includes 'Device' and 'Measurement'. Under 'Device', there are subclasses like 'Battery', 'Chiller', 'ElectricGenerator', 'ElectricTimeControl', 'Engine', 'FlowMeter', 'MeterDevice', 'SolarDevice', and 'Tank'. Under 'Measurement', there are subclasses like 'Bess', 'Bipv', 'EvCharger', 'Flow_Meter', 'HSC', 'LHTS', 'mCHP', 'Meter_Measurement', and 'VAWT'. The 'EvCharger' class is highlighted. The right pane shows the 'Annotations: EvCharger' section, which is currently empty. Below it, the 'Description: EvCharger' section lists several properties and their values:

- Equivalent To: +
- SubClass Of: +
- active_power_totalMeasuredIn value kilowatt
- connectorStatusMeasuredIn value NULL
- departure_timeMeasuredIn value seconds
- evmax_phaseMeasuredIn value A
- inactive_energyMeasuredIn value kilowatt_h
- measuredByDeviceType value ElectricTimeControl
- Measurement
- relatesToProperty value ev_charger
- required_energyMeasuredIn value kilowatt_h
- Vehicle_numPhaseMeasuredIn value NULL

❖ RE-COGNITION CIM – Data Modelling(3)

The screenshot displays the Protégé ontology editor interface. The browser address bar shows the URL: <http://www.certh.gr/recognition/ontology/1.0.0>. The main window is titled 'relatesToProperty' and shows an 'Object property hierarchy' for 'relatesToProperty'. The hierarchy is as follows:

- owl:topObjectProperty
 - hasDeviceType
 - hasType
 - measuredByDeviceType
 - MeasuredIn
 - BessMeasuredIn
 - P_bess_acMeasuredIn
 - SoCMeasuredIn
 - BipvMeasuredIn
 - energy_yieldMeasuredIn
 - p_outMeasuredIn
 - EvChargerMeasuredIn
 - active_power_totalMeasuredIn
 - connectorStatusMeasuredIn
 - departure_timeMeasuredIn
 - evmax_phaseMeasuredIn
 - inactive_energyMeasuredIn
 - required_energyMeasuredIn
 - Vehicle_numPhaseMeasuredIn
 - Flow_MeterMeasuredIn
 - ExpMeasuredIn
 - EimpMeasuredIn
 - P_DtotMeasuredIn
 - PtotMeasuredIn
 - HSCMeasuredIn
 - Pel_auMeasuredIn
 - Pel_coolingMeasuredIn
 - Pth_coolingMeasuredIn
 - tregMeasuredIn
 - LHTSMeasuredIn
 - G_w_cMeasuredIn
 - G_wdMeasuredIn
 - LHTS_E_thMeasuredIn
 - State_of_chargeMeasuredIn
 - T_ch_inMeasuredIn
 - T_ch_outMeasuredIn
 - T_w_inMeasuredIn
 - T_w_outMeasuredIn
 - mCHPMeasuredIn
 - E_elMeasuredIn
 - E_thMeasuredIn
 - Pel_outMeasuredIn
 - Pth_outMeasuredIn
 - Meter_measurementMeasuredIn
 - VAWTMeasuredIn
 - powerMeasuredIn

The 'relatesToProperty' property is selected, and its characteristics are shown in the right-hand pane:

- Functional
- Inverse functional
- Transitive
- Symmetric
- Asymmetric
- Reflexive
- Irreflexive

Additional options in the right-hand pane include:

- Equivalent To (+)
- SubProperty Of (+)
- Inverse Of (+)
- Domains (intersection) (+): Measurement
- Ranges (intersection) (+): Property
- Disjoint With (+)
- SuperProperty Of (Chain) (+)

❖ RE-COGNITION CIM – Data Modelling(4)

The screenshot displays an ontology editor interface for the 'ontology' (http://www.certh.gr/recognition/ontology/1.0.0). The main view shows the 'Data property hierarchy: connectorStatus' with a tree structure on the left and a 'Description: connectorStatus' panel on the right.

Data property hierarchy: connectorStatus

- owl:topDataProperty
 - bessValues
 - P_bess_ac
 - Soc
 - bipvValues
 - energy_yield
 - p_out
 - EvChargerValues
 - active_power_total
 - connectorStatus
 - departure_time
 - evmax_phase
 - inactive_energy
 - required_energy
 - Vehicle_numPhase
 - FlowMeterValues
 - Eexp
 - Eimp
 - P_Dtot
 - Ptot
 - hasState
 - HSCValues
 - PeI_au
 - PeI_cooling
 - Pth_cooling
 - treg
 - LHTSValues
 - E_th_LHTS
 - G_w_c
 - G_wd
 - State_of_charge
 - T_ch_in
 - T_ch_out
 - T_w_in
 - T_w_out
 - mCHPValues
 - E_el

Annotations: connectorStatus

Annotations +

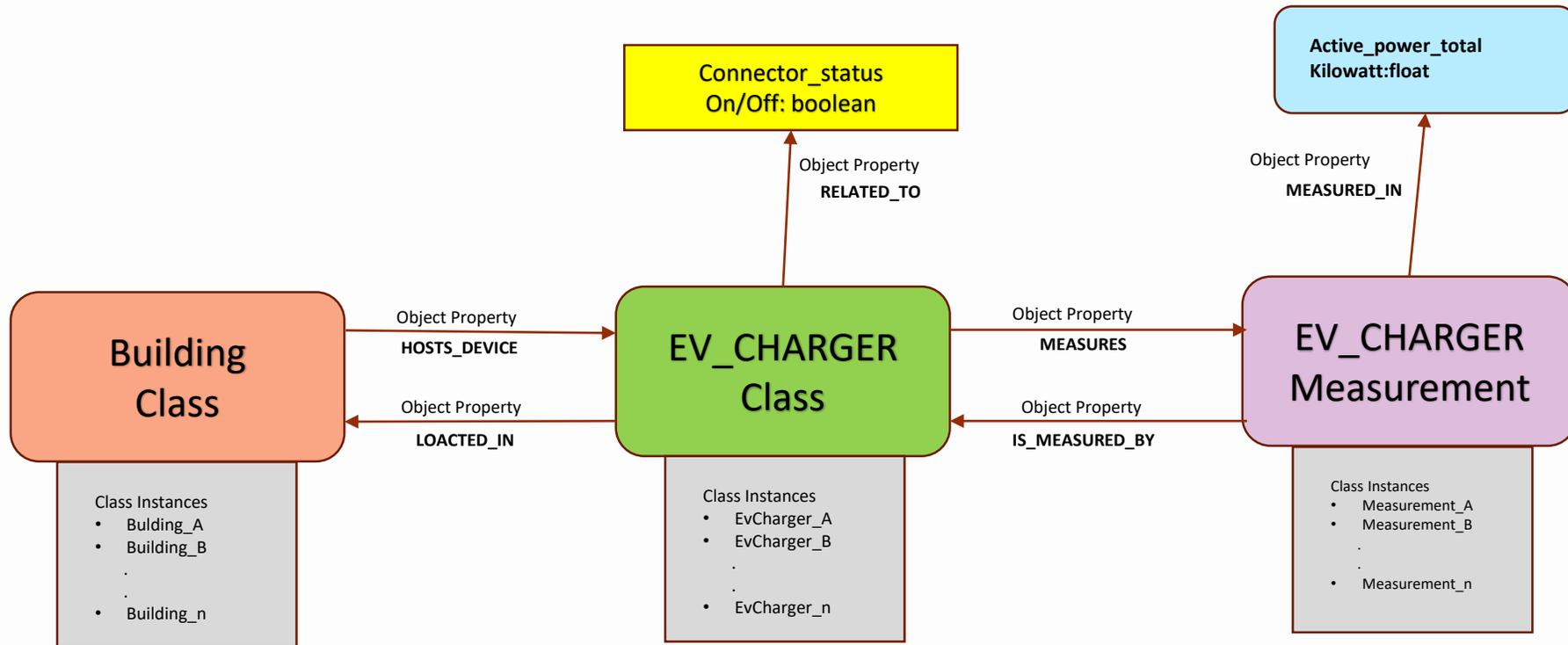
Characteristics: connectorStatus

Functional

Description: connectorStatus

- Equivalent To +
- SubProperty Of +
 - EvChargerValues
- Domains (intersection) +
 - EvCharger
- Ranges +
 - xsd:integer
- Disjoint With +

❖ RE-COGNITION CIM – Data Modelling(5)



❖ Data models in JSON_LD format

mCHP_command payload

```
1 {
2   "data": {
3     "@id": "Pre-Pilot-data",
4     "@type": "Command",
5     "@context": {
6       "core": "http://purl.org/ontology/cim#"
7     },
8     "label": "Recognition CIM Example",
9     "location": "Certh",
10    "operation": "4",
11    "hasName": "",
12    "hasVersion": "v1",
13    "hasTimestamp": "",
14    "consists_of": [
15      {
16        "@type": "Engine",
17        "hasState": 0,
18        "relatesToProperty": "mchp",
19        "consists_of": [
20          {
21            "@type": "Pth_setpoint",
22            "hasValue": {
23              "@type": "xsd:float",
24              "@value": 0
25            },
26            "isMeasuredIn": {
27              "@id": "percent"
28            }
29          }
30        ]
31      }
32    ]
33  }
34 }
35
```

Bipv_measurement payload

```
1 {
2   "data": {
3     "@id": "Pre-Pilot-data",
4     "@type": "Measurement",
5     "@context": {
6       "core": "http://purl.org/ontology/cim#"
7     },
8     "label": "Recognition CIM Example",
9     "location": "Certh",
10    "operation": "4",
11    "hasName": "",
12    "hasVersion": "v1",
13    "hasTimestamp": "",
14    "consists_of": [
15      {
16        "@type": "ElectricGenerator",
17        "hasState": 0,
18        "relatesToProperty": "vawt",
19        "consists_of": [
20          {
21            "@type": "power",
22            "hasValue": {
23              "@type": "xsd:float",
24              "@value": 0
25            },
26            "isMeasuredIn": {
27              "@id": "watt"
28            }
29          }
30        ]
31      }
32    ]
33  }
34 }
35
```

❖ RE-COGNITION CIM – Final Version(2)

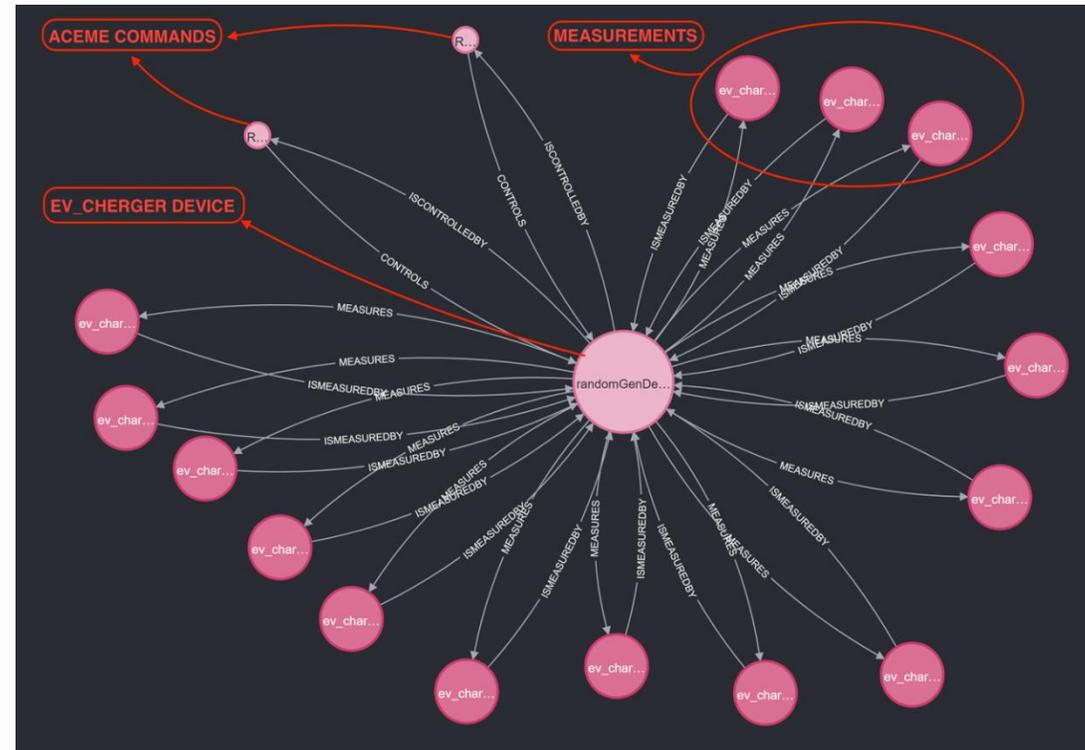
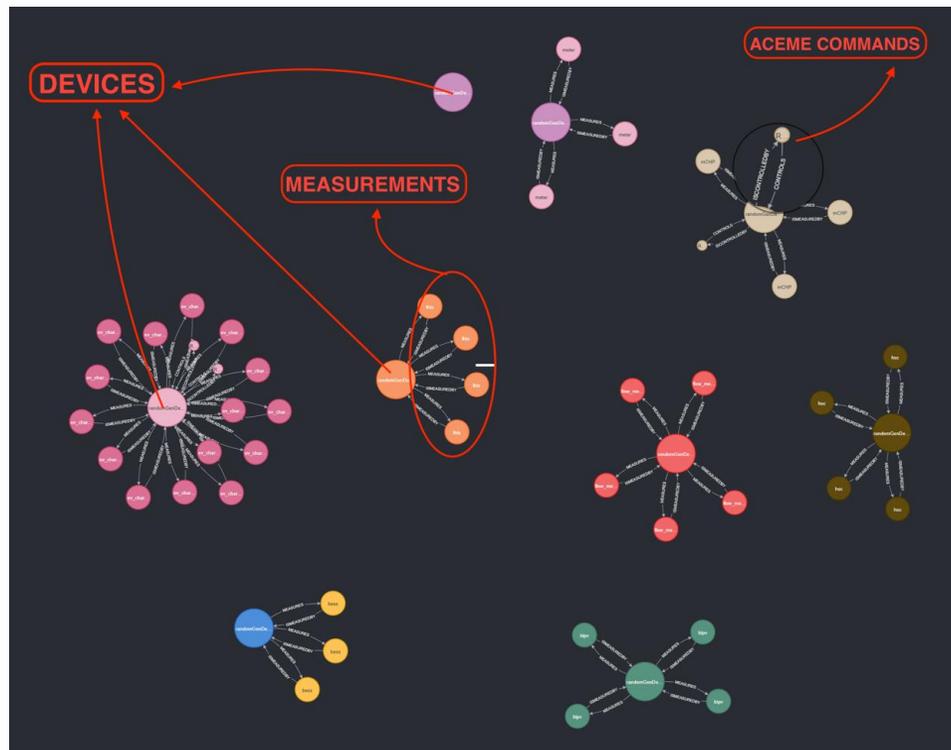
2. CIM Repository:

- Implemented with a graph Database
- Functioning in parallel with RE-COGNITION main SQL-based database
- Both databases get updated simultaneously
- Faster performance than traditional relational databases in retrieving very big amounts of data
- Used for generating energy statistics for buildings under observation
- Neo4J Framework
 - ✓ Python driver availability
 - ✓ Docker friendly
 - ✓ Great Visualization Tool

❖ RE-COGNITION CIM – Final Version(3)

3. Visualization

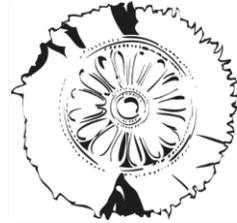
- Graph Visualization in testing stages
- Zoomed in a IoT device installed on and Ev Charger



Thank you

Questions?

Project Partners



POLITECNICO
MILANO 1863



Funded by
the European Union

This project has received funding from the European Union's Horizon research and innovation programme under grant agreement No 101078997

