



A semantic-based framework for energy management in Home and Building Automation scenarios

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Outline



- Home and Building Automation (HBA): state of the art
- Ambient Intelligence vision
- Knowledge-based HBA: framework and approach
- Agent Framework
- Case Study: Energy Management in HBA
- Conclusion and future work

■ Goal

- Increase comfort and building efficiency
- Decrease waste and maintenance costs
- Integration of different home systems

■ Most important HBA standards:



- ZigBee (HA Profile)



- LonWorks



- X-10

- EIB/KNX

- low cost
- widespread
- ethernet support (KNXnet/IP protocol)



Classic Domotics

- Static and not flexible architectures
- Constrained interoperability
- Reduced functionalities and scenarios
- User-driven interaction (low autonomicity)



Agent-based Domotics

- Flexible and scalable
- Services and resources accessible via agent-oriented frameworks
- Concurrency, cooperation, negotiation enabled



Semantic-based Domotics

- Improved interoperability
- Rich description of user/service profiles
- Decentralized architecture supporting autonomous device-driven interactions



- **Knowledge-based agent** framework for Home and Building Automation (HBA) [Ruta *et al.*, IEEE-TII, 2011]:

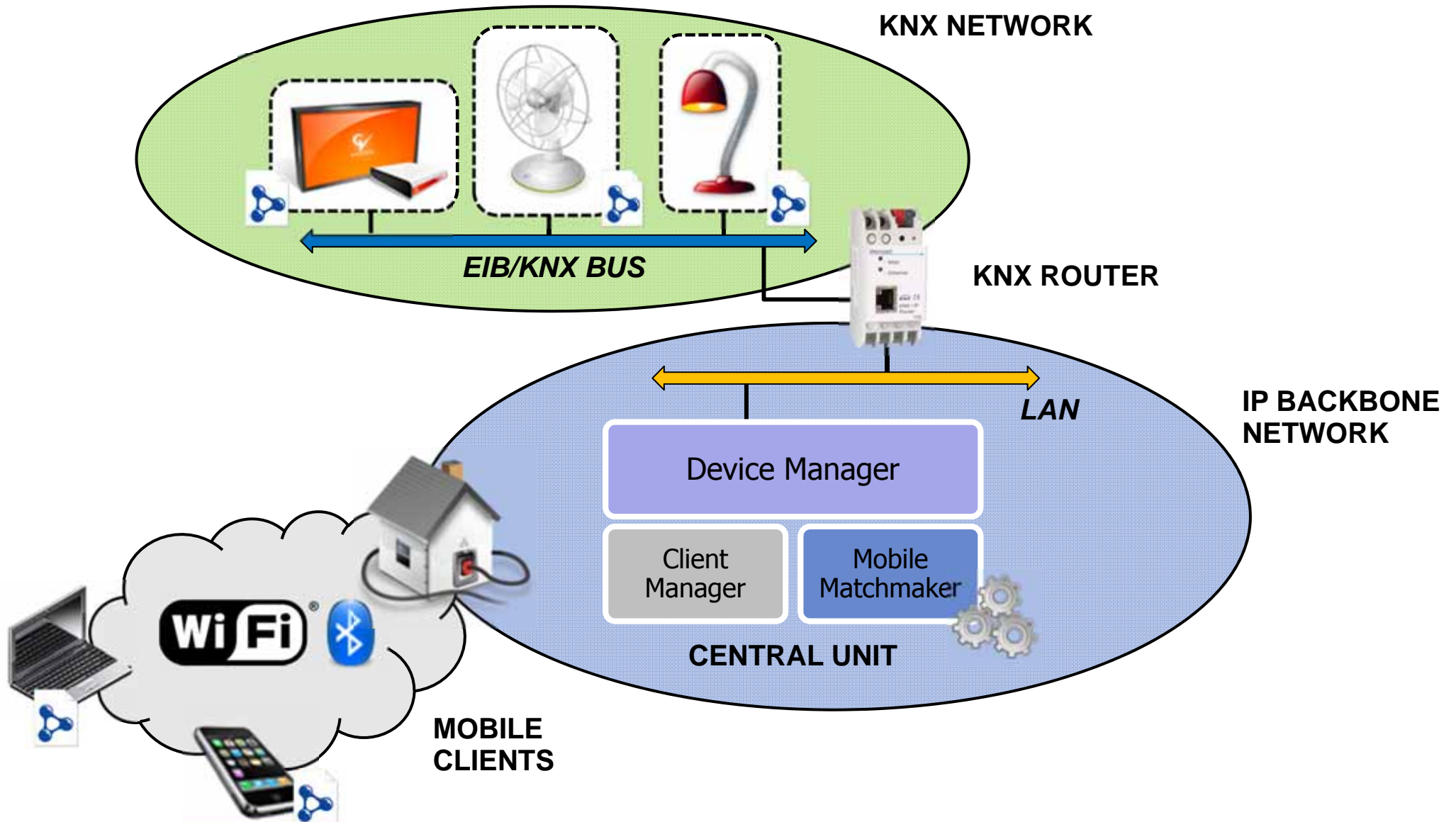


- **home self-configuration** through collaboration of autonomous smart agents
- semantic annotation of user profiles, device settings and appliance behaviors **w.r.t. an OWL-DL ontology** modelling typical home environments

- **Smart profiling agent** (running on smartphones) [Loseto *et al.*, WOA, 2013] able to:



- perform a **multimodal** (*i.e.*, involving several **heterogeneous** data sources) and continuous sensing **without human intervention**
- mine the user habits automatically and build a **logic-based daily profile** exploited in context-aware HBA applications



- **Semantic-based enhancement of EIB/KNX** protocol standard [Ruta *et al.*, IEEE ICM, 2011]:
 - integration of a semantic micro-layer preserving a full backward compatibility
 - advanced service and resource discovery support
- **Logic-based negotiation process** to:
 - adapt **concept covering** [Ragone *et al.*, JWSR, 2007] to select one or more functionalities whose combination fills the user/device request
 - negotiate on available home and energy resources through a user-transparent and **device-driven** interaction
 - discover the (set of) elementary services that **maximize** the overall utility
 - support non-expert users in selecting home configurations ranked w.r.t. a global utility



- **Prototypical Testbed** representing a small set of home environments equipped with different **KNX-compliant** off-the-shelf devices



Testbed



Main Panel

Camera



Weather Station



Alarm





Prototypical Testbed: Central Unit GUI



Weather

14 °C **Bari, Italy**

Tue, 11°/19° C

Wed, 9°/18° C

Thu, 7°/16° C

Fri, 8°/16° C

Weather: none
Temperature: none
Wind Speed: none
Brightness: none

Home Devices

Energy Providers

Network Status

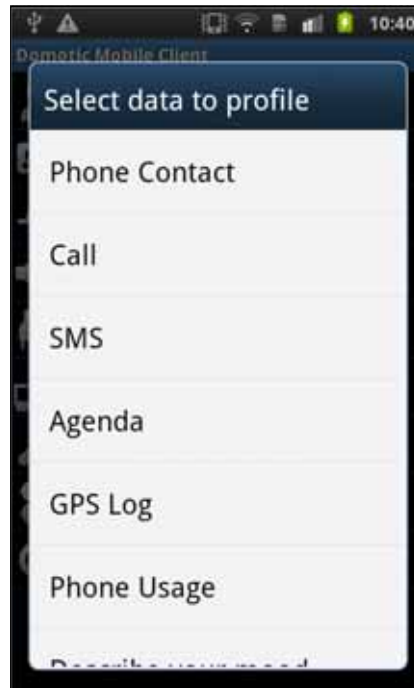
LOCALHOST: 127.0.0.1
KNX ROUTER: 127.0.0.100
KNX NETWORK: SIMULATED
KNX DATA: ---
QoS: ---

Quick Profiles

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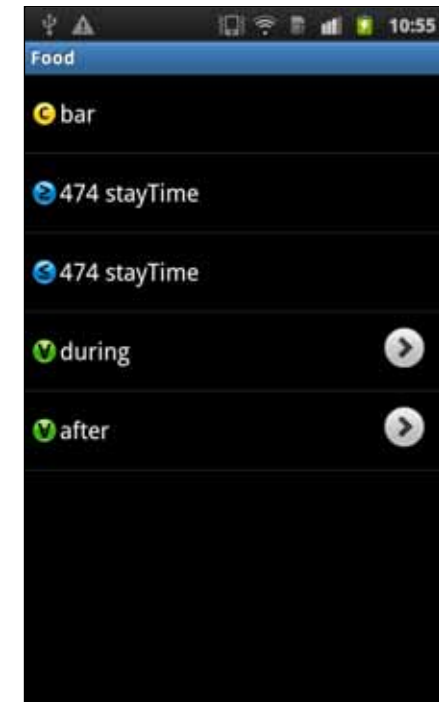
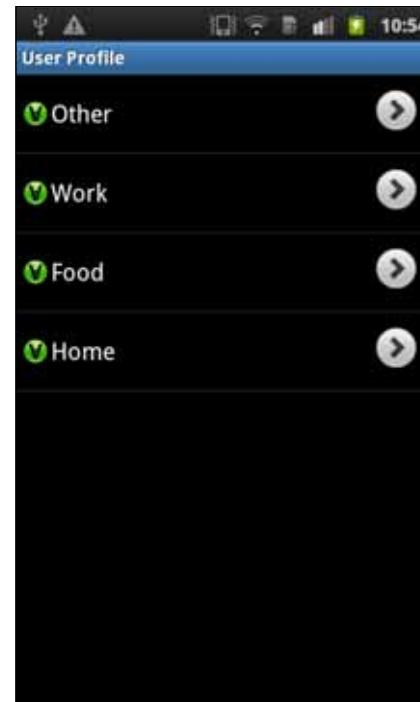
Power Consumption

1.2 kWatt (kW)



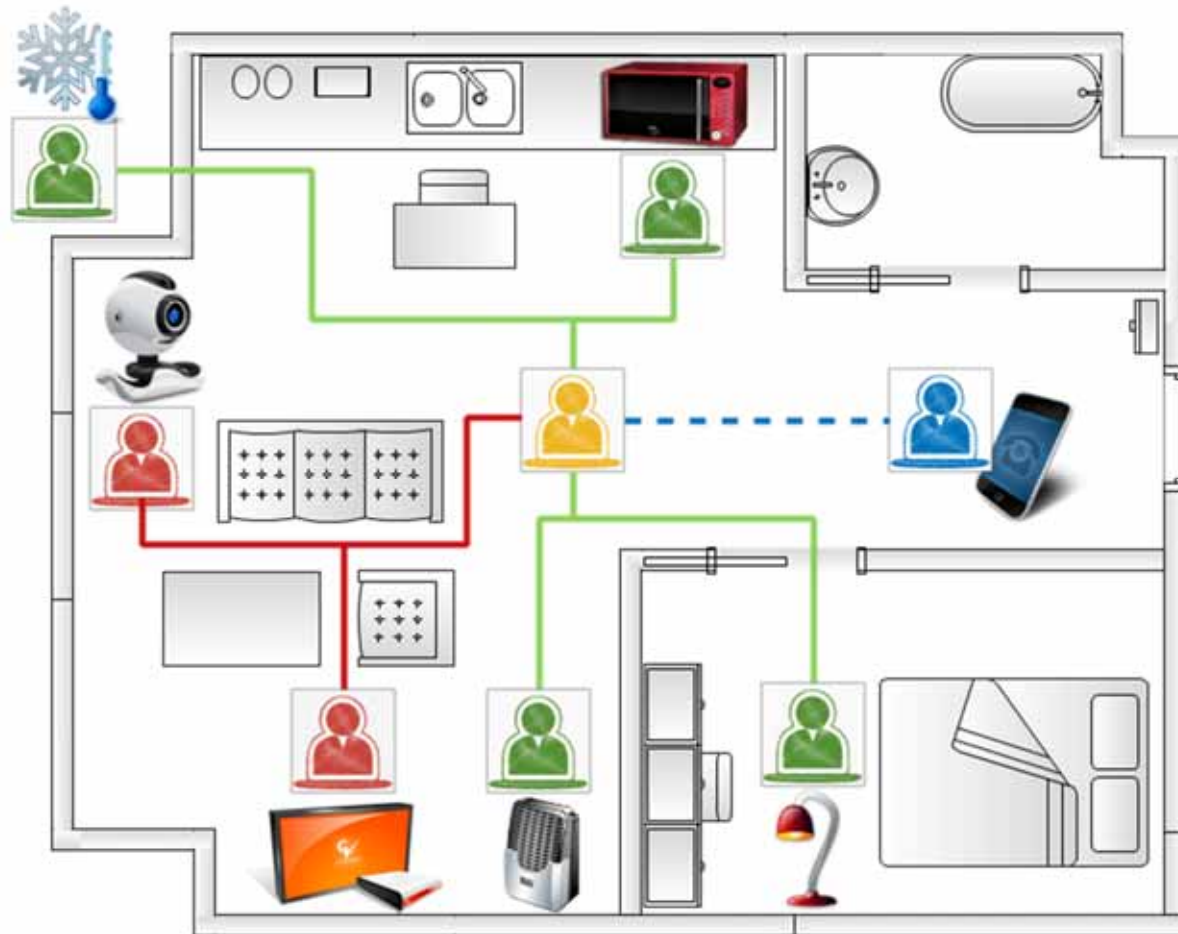
Goals:

- Avoid **explicit** user interaction
- **Automatically** detect user needs by exploiting information available on her smartphone



Features:

- Identify the daily **stay points**
- Retrieve the nearest **Point Of Interest (POI)** querying suitable Web services
 - Google Places
 - LinkedGeoData [Stadler *et al.*, SWJ, 2012]
- Build a **daily user profile**



User Agent
(WiFi communication)

exposes user needs and preferences



Mediator Agent

acts as a mediator in a negotiation round



KNX Device Interface Agent
(Semantic enhanced KNX protocol)

supports KNX enhancements in case of legacy appliances



Smart Device Agent
(Direct communication over IP network)

sends semantic-based requests to the mediator agent for negotiating a home profile

REQUEST



User Request

suggestedForSensation.Cold
= 10 outside Temperature

ENERGY PROVIDERS



E₁: Electric Grid

suggestedForEnergyProvider. Renewable
availableKWh = 1



E₂: Photovoltaic System

suggestedForEnergyProvider.Renewable
availableKWh = 4

SERVICES

S₁: Heat Pump

suggestedForSensation.Cold
≥ 8 outside Temperature
≥ 1 available kWh



S₂: Heater at Half power

suggestedForSensation.Cold
≤ 7 outside Temperature
≥ 3 available kWh



S₃: Heater at Full Power

suggestedForSensation.Cold
≤ 2 outside Temperature
≥ 6 available kWh



Select suitable services

Rank by compatibility

Rank by efficiency

Select service/provider pairs

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E₂: Photovoltaic System

suggestedForEnergyProvider.Renewable
availableKWh = 0



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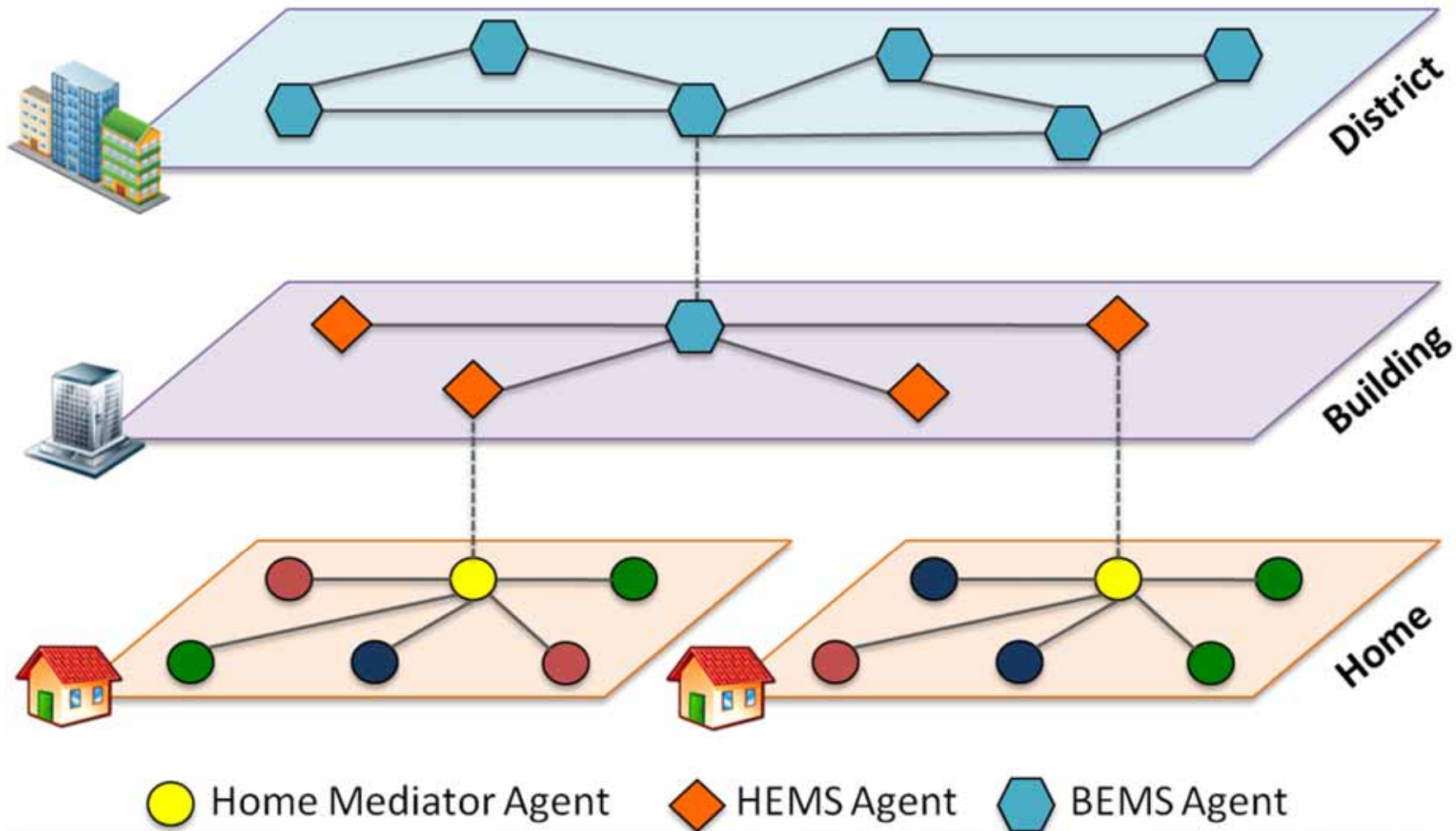
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Rank by compatibility

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Select service/provider pairs

Framework extension for home, building and district energy management in a Smart Grid vision





Future work directions



- Integrate to the general framework:
 - additional domotic **protocols** (Lonworks, ZigBee)
 - Semantic Sensor Networks (SSN) based on Constrained Application Protocol (**CoAP**) protocol [Ruta *et al.*, IEEE iThings, 2013]
- Improve the automatic **user profiling** module
- Extend the prototypical testbed toward the proposed **Smart Grid** vision with new off-the-shelf devices and sensors
- Evaluate the approach with a **large-scale simulation** campaign within a Neighborhood Area Network (NAN)
- Integration with JEMMA Project
 - Mine data about electric **energy consumption** for energy-based home and building profiling
 - Alignment of the current HBA ontology with Energy@Home data model