DOG: an Ontology-Powered OSGi Domotic Gateway

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Outline

1. **Introduction**
2. **Objectives**
3. **DOG**
   - Ring 0
   - Ring 1
   - Ring 2
   - Ring 3 bundles
4. **DogOnt**
5. **Ontology-based Operations in DOG**
6. **Conclusions**

Domotics

Information technology in the home

- Remote lighting and appliance control have been used for years (see X10)
- Nowadays domotics is another term for the digital home, including: the networks and devices that add comfort and convenience as well as security;
- Domotics means controlling heating, air conditioning, food preparation, TVs, stereos, lights, appliances and security system of the home

Domotics – Drawbacks (1/2)

Many vendors on the market with not compatible solutions

- Different technologies (bus, powerline, wireless)
- Different protocols (KNX, MyOpen, X10, LonWorks)
- Different device features
- Different sophistication of device firmware (from simple relay to full software-based operation)

Domotics – Drawbacks (2/2)

Rooted on Simple Electric Automation

- Only simple automation is supported
  - Simple scenarios
  - Fixed, programmed behaviors
  - Simple comfort, security and energy saving policies
- No support for more complex interactions
  - Adaptation to user preferences
  - Context detection
  - Structural verification
  - Static and dynamic reasoning on the house state

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Goal

Evolving into Intelligent Domotic Environments (IDEs)

Supporting Interoperation, Integration and Intelligence by

- Adding a single (cheap) device for
  - interoperating different domotic plants
  - implementing complex behaviors
- Modeling environments in a semantic-rich, technology independent way
- Providing suitable querying and reasoning mechanism over the environment model

Domotic Systems vs Smart Home

Smart Home

- Pros
  - supports complex and intelligent behaviors
- Cons
  - home pervaded by sensors and actuators
  - dedicated hardware and software
  - Experimental and futuristic connotation
  - Very expensive

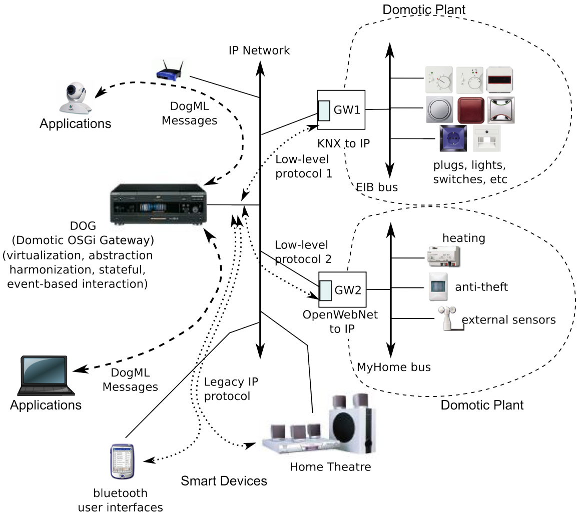
Domotic Systems

- Pros
  - Commercial solution
  - Modular and (relatively) easy to install and configure
  - Affordable costs
- Cons
  - Sparse technologies
  - Only supports simple automation
  - No support for intelligent behaviors

Starting considerations

- The sparseness of domotics solutions, the differences in languages, communication means and protocols is very similar to the “old web”
- Semantic Web technologies can help solving
  - Interoperation issues
  - Integration of different technologies
- and can support home intelligence through
  - Reasoning
  - Context Modeling
  - ...

Anatomy of an Itelligent Domotic Environment



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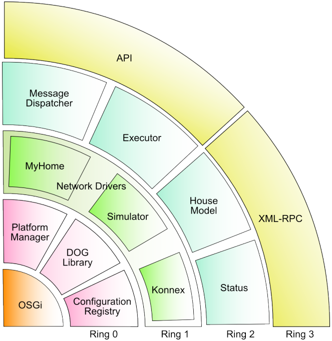
DOG

- DOG (**D**omotic **O**SGi **G**ateway) is a Domotic House Gateway designed for transforming commercial Domotic Systems into Intelligent Domotic Environments.
- Based on **OSGi** architecture.
- DOG provides
  - Interoperation between different domotic networks through proper drivers
  - Technology independent, ontology-based, house and device modeling
  - Advanced, inter-network, rule-based scenario definition and operation
- **DogOnt** is the ontology model lying at the basis of DOG

DOG Architecture

- Ring 0: the DOG common library and communication between the OSGi platform and the other rings
- Ring 1: interface to the various domotic networks
- Ring 2: routing infrastructure for messages and intelligence core of DOG (DogOnt)
- Ring 3: access to external applications



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Ring 0 bundles

Dog library

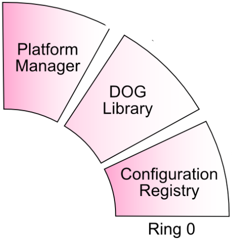
Library repository for all other DOG bundles. Provides the interfaces of the services implemented by DOG bundles.

Platform Manager

Handles the start-up of the whole system and manage the life cycle of DOG bundles.

Configuration Registry

Stores configuration information about each bundle.



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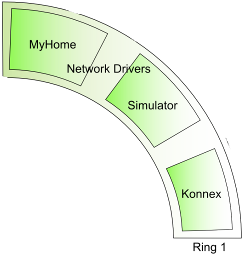
Ring 1 bundles

Network Drivers

- A Network Driver for **each** different domotic technology (e.g. KNX, OpenWebNet, X10, etc.)
- *Self-configuration* phase in which they retrieve the list of devices from the **House Model**.
- Network drivers translate messages back and forth between Dog bundles and network-level gateways.



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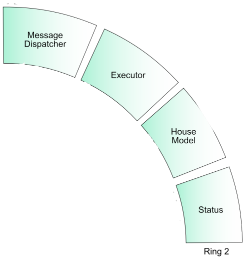
Ring 2 bundles (1/2)

Message Dispatcher

Internal router, delivering messages (commands, state polls or notications) to the correct destinations.

Executor

Semantically validates the command reiceved from the API and forwards to the Message Dispatcher.



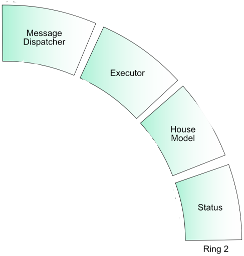
Ring 2 bundles (2/2)

Status

Caches the states of all devices controlled by DOG.

House Model

Intelligence core of DOG. Based on DogOnt ontology.



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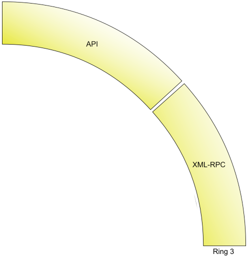
Ring 3 bundles

API

Retrieve the house configuration, to send commands to devices and to receive house events.

XmlRPC bundle

It provides an XML-RPC endpoint for services offered by API bundle. It enalbes non-OSGi applications to control DOG.



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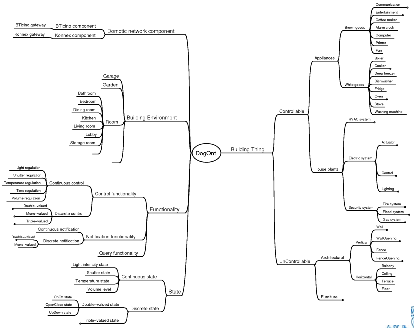
DogOnt

DogOnt is an ontology model designed for supporting Interoperation, Integration and Intelligence in domotic environments

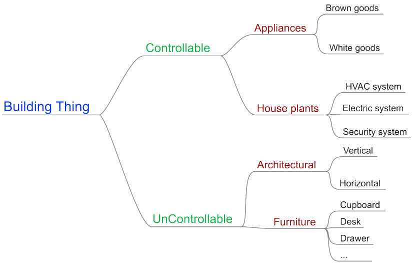
- Building Thing
- Building Environment
- State
- Functionality
- Domotic Network Component



Environment Modeling (1/2)

BuildingThing

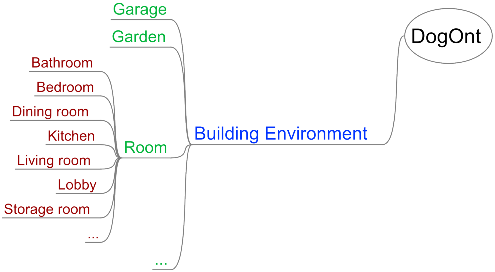
- Models all the elements of a Building Environment divided into
  - Controllable
  - UnControllable
- The UnControllable sub-tree allows to model
  - Furniture elements
  - Walls, floors, ceilings and other architectural elements (Architectural sub-tree)



Environment Modeling (2/2)

BuildingEnvironment

- Models rooms and architectural spaces composing a house
  - Rooms
  - External spaces such as garages, garden, etc.



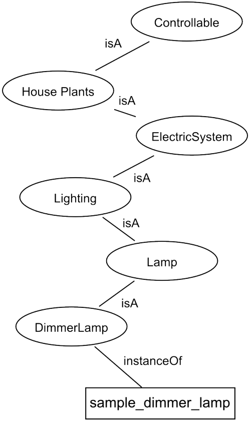
Device Modeling

- Devices are modeled independently from specific technologies
- 3 Modeling axes:
  - **Typology** - describes the type of device, separating appliances and devices belonging to house plants
  - **Functionality** - describes the tasks that a device can accomplish, by defining the available commands
  - **State** - describes the conditions in which a device can be (e.g. a Lamp can be ON or OFF)
- Technology specific aspects are modeled through separate classes
  - **NetworkComponent** - the root concept for modeling every network specific information, its sub-classes reflect the different networks supported by DOG.

Typology

Controllable devices taxonomy

- Appliances
  - Brown Goods (TV, HiFi,...)
  - White Goods (Fridge, Dishwasher,...)
- HousePlants
  - Electric
  - HVAC (Heating Ventilation & Air Conditioning)
  - Security



Functionalities (1/3)

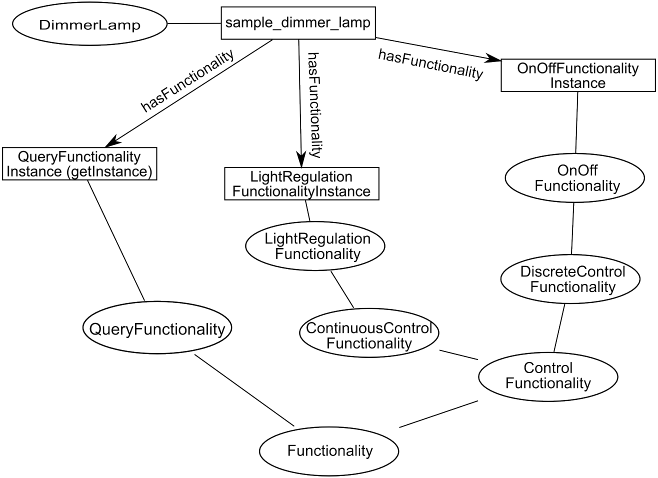
- Control Functionalities
  - Model the ability of a device to be controlled
  - Define the possible commands and their range (needed for continuous functionalities)
  - Almost every Controllable has a control functionality
- Notification Functionalities
  - Model the ability of a device to issue a notification about state/configuration changes
  - Define the possible notifications
  - Typical of Sensors and Buttons/Switches
- Query Functionalities
  - Model the ability of a device to be queried about its state/configuration
  - It's defined **for all** Controllables

Functionalities (2/3)

Every Functionality class is subdivided into

- Continuous Functionalities
  - Model the ability to change device properties in a continuous manner (e.g. dimming the light emitted by a lamp)
- Discrete Functionalities
  - Model the ability to abruptly change device properties (e.g. switching a lamp On)

Functionalities (3/3)

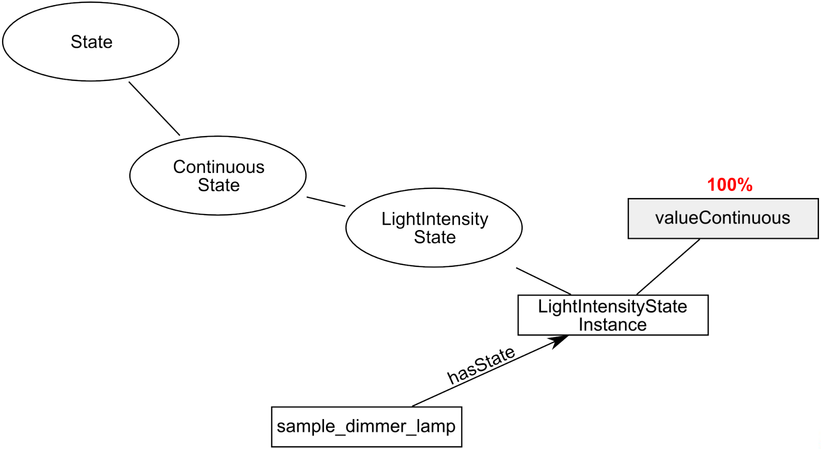

DimmerLamp
sample_dimmer_lamp
hasFunctionality
hasFunctionality
hasFunctionality
OnOffFunctionality Instance
QueryFunctionality Instance (getInstance)
LightRegulation FunctionalityInstance
OnOff Functionality
LightRegulation Functionality
DiscreteControl Functionality
QueryFunctionality
ContinuousControl Functionality
Control Functionality
Functionality

States (1/2)

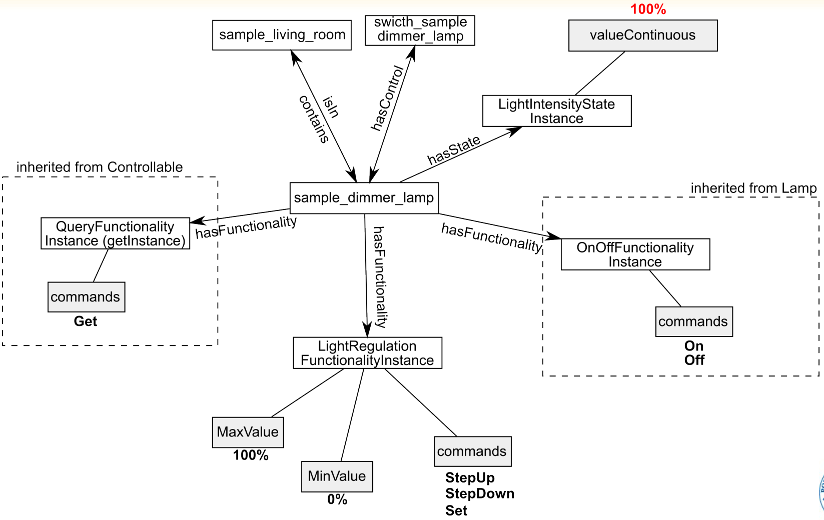
States are classified according to the kind of values they can assume

- Continuous states
  - Model continuously changing qualities (e.g. the current dimming level of a lamp)
  - The current state value is stored in the *continuousValue* property.
- Discrete states
  - Model discretely changing qualities (e.g. the lamp being On or Off)
  - The current state value is stored in the *discreteValue* property.
  - Possible states are listed in the *possibleStates* property.

States (2/2)


State
Continuous State
LightIntensity State
100%
valueContinuous
LightIntensityState Instance
hasState
sample_dimmer_lamp

DimmerLamp modeling example



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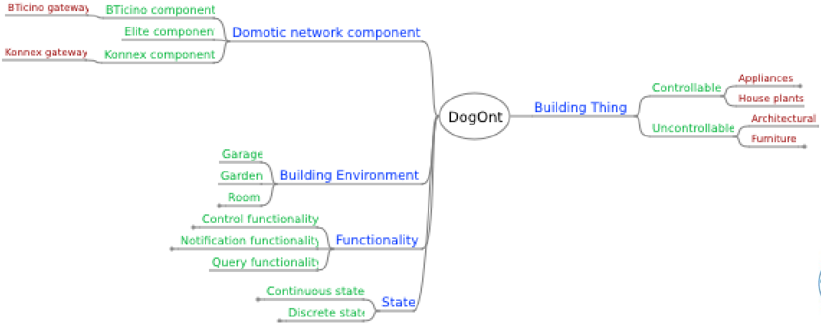
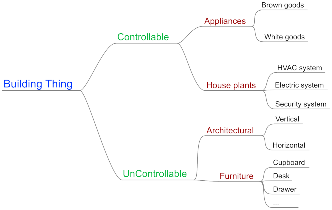
House Model and DogOnt (1/2)

- The House Model is the core of the DOG intelligence.
- It is based on a formal model defined by DogOnt ontology.
- DogOnt is designed for supporting Interoperation, Integration and Intelligence in domotic environments
- DogOnt supports several critical features of DOG



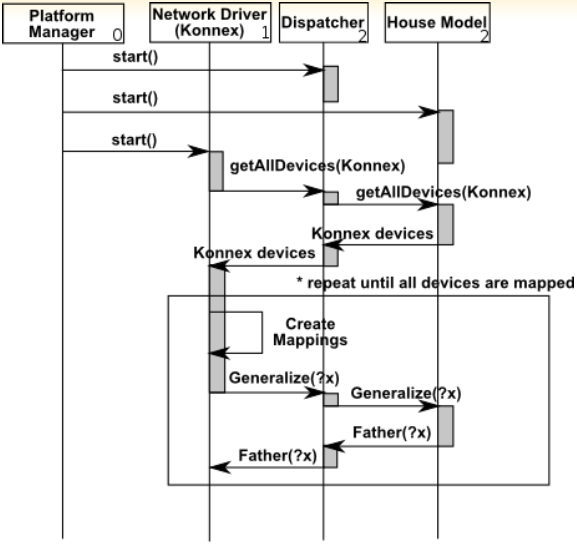
House Model and DogOnt (2/2)

- A central **point of configuration** for devices
- specific **uniform set of devices, states and functionalities**
- Enables **syntactic and semantic check of commands**
- Top-down **inter-plant** scenarios which involve devices
- Provides interoperation between plants (e.g. allowing a BTicino button to control a KNX light)

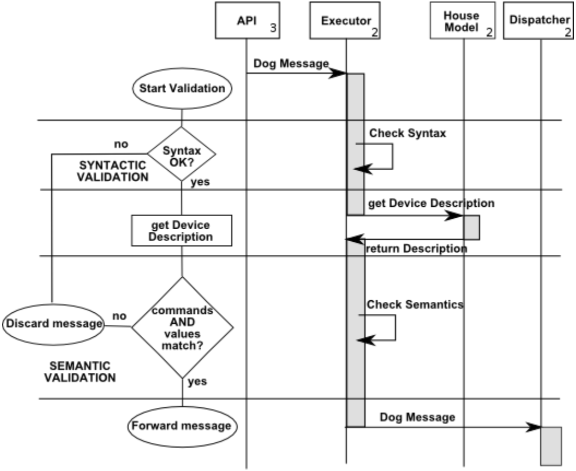


- Building Thing
  - Controllable
    - Appliances
      - Brown goods
      - White goods
    - House plants
      - HVAC system
      - Electric system
      - Security system
  - UnControllable
    - Architectural
      - Vertical
      - Horizontal
    - Furniture
      - Cupboard
      - Desk
      - Drawer
      - ...

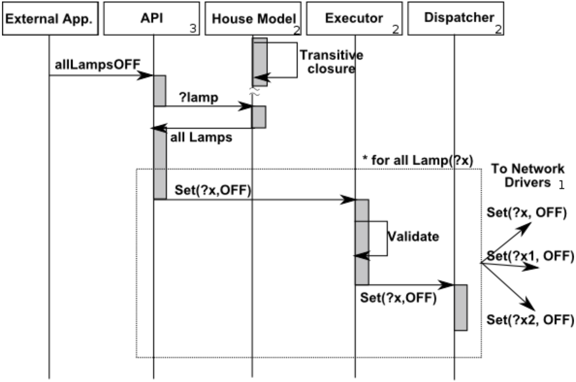
Start-up


Platform Manager 0
Network Driver (Konnex) 1
Dispatcher 2
House Model 2
start()
start()
start()
getAllDevices(Konnex)
getAllDevices(Konnex)
Konnex devices
Konnex devices
* repeat until all devices are mapped
Create Mappings
Generalize(?x)
Generalize(?x)
Father(?x)
Father(?x)

Command Validation

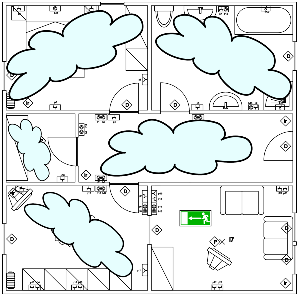


Inter-network scenarios



Advanced Intelligence in DOG

- Transitive closure and Classification Reasoning to **decouple evolution of the model and domotic systems**
- Structural verification of domotic environments through SWRL constraints
- Dynamic detection of safety critical situations (smoke propagation, safe exit path) using rule-based reasoning
- On-going work on automatic generation of interoperation rules from DogOnt



Experimental set-up

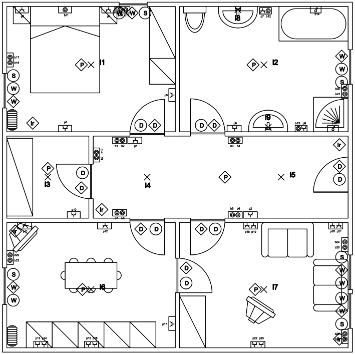
Technologies

- Eclipse Equinox OSGi framework
- Jena and Pellet
- MyOpen and KNX

Components

- DOG runs on an ASUS eeePC701
    - 900MHz Celeron processor
    - 512MByte RAM
    - 4GByte SSD
- KNX demo case built by the authors
- MyOpen demo case offered by BTicino

Reference Environment



Domotic Devices

- 27 Push Buttons
- 7 Lamps
- 23 Plugs
- 7 Door Actuators
- 7 Door Sensors
- 6 Window Actuators
- 6 Window Sensors
- 6 Shutter Actuators
- 5 Infrared Sensors
- 6 Smoke Sensors

Ontology-based Operations in DOG

Operations supported by DogOnt

- Installation ($\simeq$ 40s)
  - Model Reasoning (transitive closure + classification)
- Start-up ($<$ 3s)
  - SPARQL queries for associating devices to drivers
- Validation (<100ms)
  - SPARQL queries for gathering allowed commands and their ranges
  - Comparison between requested and allowed operations
- Inter-network scenarios
  - SPARQL queries for gathering specific device types (e.g. Lamps)
  - Generation of commands on the basis of device types (e.g. all Lamps ON)

SPARQL queries

Controllable query excerpt

```
SELECT DISTINCT ?x ?y WHERE {{
...
UNION
{?x rdfs:subClassOf dogont:Controllable . ?x rdfs:subClassOf ?s.
?s rdfs:subClassOf [rdf:type owl:Restriction;
owl:onProperty dogont:hasFunctionality;
owl:someValuesFrom ?y] . ?y rdfs:subClassOf
dogont:Functionality;}
UNION
{?x rdfs:subClassOf dogont:Controllable . ?x rdfs:subClassOf ?s.
?s rdfs:subClassOf [rdf:type owl:Restriction;
owl:onProperty dogont:hasFunctionality;
owl:allValuesFrom ?u] . ?u owl:unionOf [
list:member[rdf:type ?v; rdfs:subClassOf ?y;]]
. ?y rdfs:subClassOf dogont:Functionality;}
...} . FILTER(?x != owl:Nothing) . FILTER(?x != owl:Thing)
}ORDER BY ?x ?y
```

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Conclusions

- We developed DOG: an ontology-powered OSGi Domotic Gateway
- Dog currently uses DogOnt ontology,that allows to control several, different, domotic plants, at the same time
- Dog will transform your Domotic plants into Intelligent Domotic Environments.

`http://domoticdog.sourceforge.net`

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