Managing unknown IoT entities by uncovering and aligning their semantics

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Internet of Things: Toward Smart Networked Systems and Societies

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Outline

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- Problem
- Future
- Present
- Solution
  - Framework
  - Ontology
  - Toolset
- Limitations
- Plans
- Q&A

The Context (IoT entities)

IoT *sensing/actuating devices*: *observe some features of interest or act on some other entities*

IoT *applications*: *utilize data sensed from sensing devices and send commands to actuating devices*

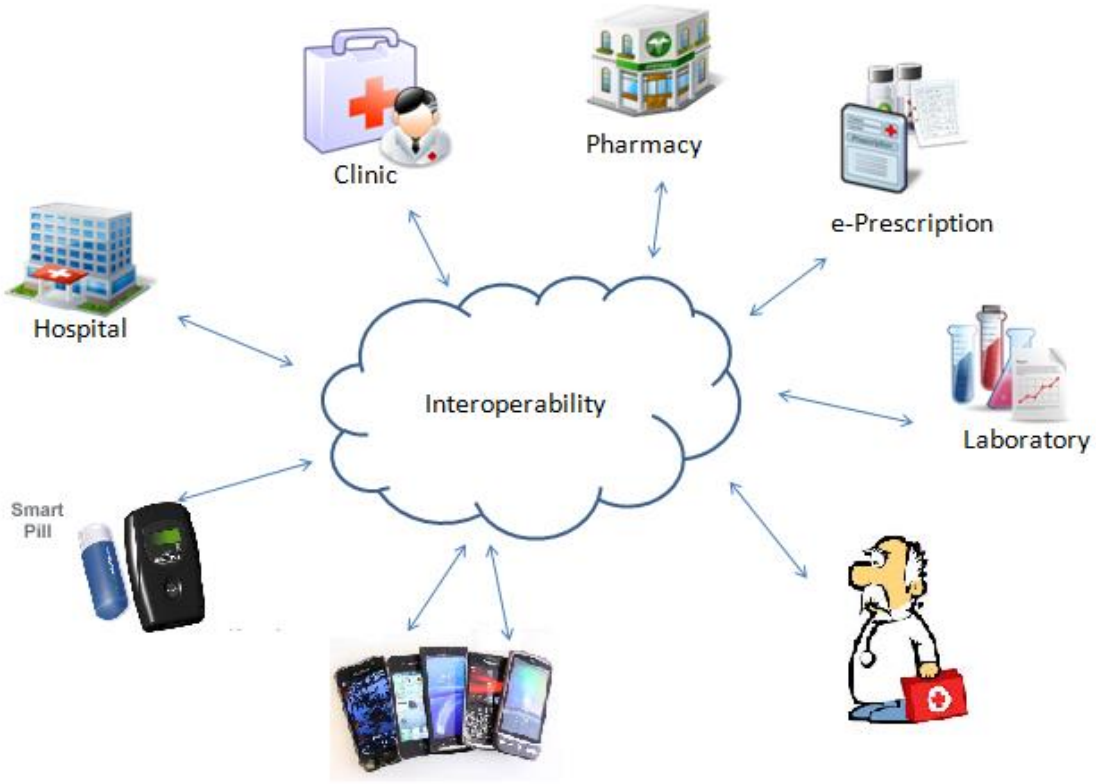
Communication between IoT devices and IoT applications

- Heterogeneous, i.e. different vendors, different models/languages to describe data and information exchanged
- "Unknown" to each other, i.e. third-party applications that are developed by vendors that are not aware of other vendors' devices' data models

Goal: automated deployment of IoT apps in unknown IoT environments

The Problem (Smart Health scenario)

- IoT **needs** semantics
- Bridge the semantic gap between IoT entities at information level



IaaS will handle all the interoperability and integration issues towards uncovering and aligning the semantics of the involved/registered IoT devices and deployed applications towards bridging their heterogeneity (syntactic or semantic).

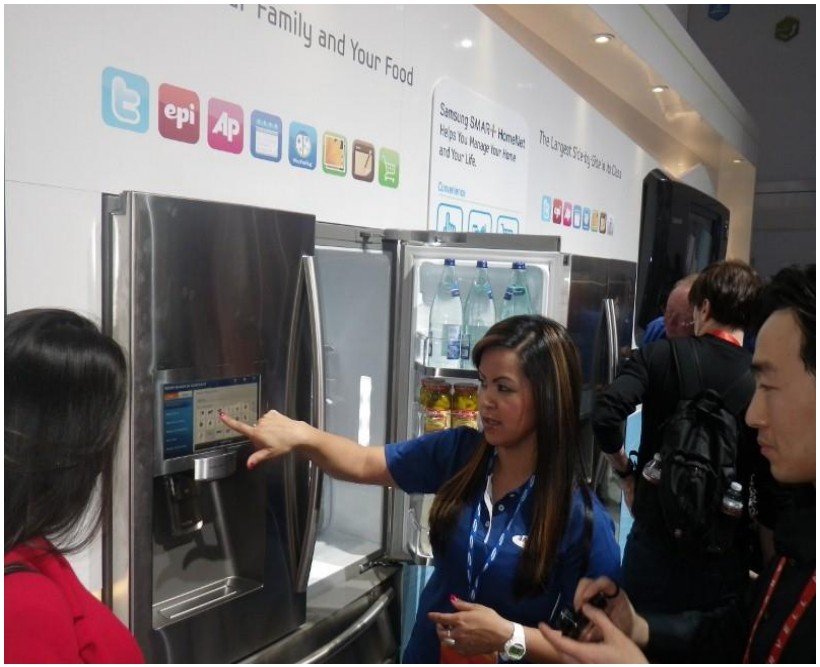
The Future

- Interconnect IoT entities from different vendors in an automated fashion
- 3rd parties develop software applications for IoT environments, contrasted to applications coming only from the devices' vendors
- Develop IoT applications that are generic, running on various IoT device sets (different vendors, same purpose), contrasted to developing applications for a very particular configuration of devices

At Present (2012 – today)

- CES 2012 to CES 2014

Smart Fridge @ Samsung



Can check your Facebook

Can send a picture from smartphone

Fridge can push to a smartphone alarms about expiring goods

Smart washing machine @ LG

At Present (2012 – today)

- CES 2012 to CES 2014

Smart fridge and oven @ LG

Fridge can have food recipes stored

A recipe can be sent to the oven

Oven will set the cooking temperature and other settings according to the recipe

At Present (2012 – today)

- CES 2012 to CES 2014

Home Automation

All is about:

- Gateway "boxes" to access data from and control devices.
- Interfaces for users

Smartphone as a "remote control for life" (mobile apps used for controlling home automation, home appliances, etc.)

At Present

- 3 Choices:
  - Buy all the devices from one vendor, **OR**
  - Connect “smart” devices (phones, TVs) from different vendors through installing a particular software client (from one vendor) on each of them (limited list of supported platforms), **OR**
  - Use a particular gateway box, then can connect devices from different vendors (from a limited list of supported by the gateway)
- **In all three cases, a single vendor is responsible for all of the “interoperability”**

The Solution

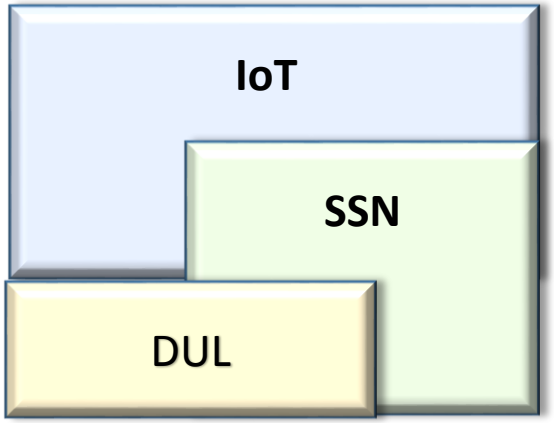
- IoT Semantic Smart Gateway Framework (**IoT-SSGF**):
- **IoT ontology** as a semantic registry for IoT entities
- **Smart Gateway toolset**
  - registered entities' data message format transformation (from XML/JSON/URI to OWL),
  - the automatic alignment of these transformations
  - the matchmaking of registered IoT entities

The Ontology

- As a Semantic Registry for IoT entities
- On top of DUL and SSN

http://purl.org/IoT/iot-ontology.owl

http://ai-group.ds.unipi.gr/kotis/ontologies/IoT-ontology



a) Abstract technological heterogeneity (vast amount of heterogeneous IoT entities)

a) Abstract semantic heterogeneity (use of heterogeneous domain ontologies to semantically annotate data of IoT entities)

The Ontology (cont.)

- ***Requirement 1***: An IoT ontology must represent any IoT physical entity that needs to be registered, managed and involved in the deployment of IoT applications

- ***Requirement 2***: An IoT ontology must represent high-level IoT entities as abstractions of physical entities' associations

- ***Requirement 3***: An IoT ontology must facilitate the representation of ontology alignment related information

The Ontology (cont.)

“Smart Room” example description:

```
:E023 a iot:Room.
:SmartRoom a iot:SmartEntity;
        ssn:featureOfInterest :E023;
        dul:includesObject :MotionDetector;
        dul:isConceptualizedBy [
                a iot:SoftwareAgent;
                iot:providesService :DetectionService
                ] .
```

“Smart Lamp” example description:

```
:Lamp a dul:DesignedArtifact, :LampType .
:LampType a owl:Class; rdfs:label "Light"@en .
:Switch a iot:Actuator, iot:ActuatingDevice.
:SmartLamp a iot:SmartEntity;
        ssn:featureOfInterest :Lamp;
        dul:includesObject :Switch.
```

The Ontology (cont.)

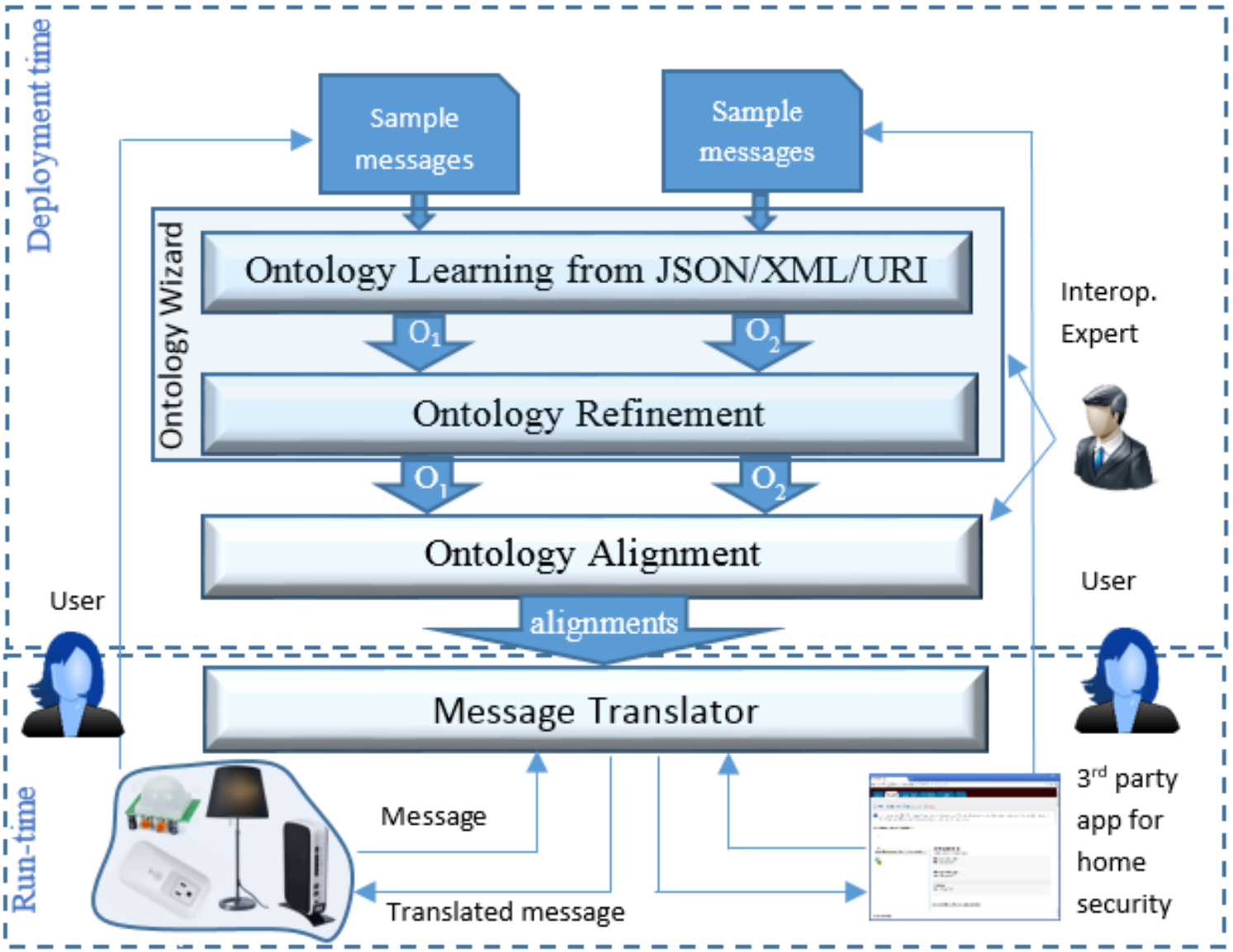
Example application ("control entity") registration:

```
:Control a iot:ControlEntity;
        dul:isConceptualizedBy :Application .
        :Application a iot:Application;
        iot:providesService :LightService .
```

"switch a light when a movement is detected in the room"

The instantiation of the specific service that the IoT service provider (application developer) provides is described in our IJDST paper

The Smart Gateway



Example data messages

ThereGate to App (in JSON):

```
{
  "List": [
    {
      "TimeStamp": 1333450241.736228,
      "Signal": "PropertiesChanged",
      "data": {
        "MotionDetected": true
      },
      "IDeviceId": 25
    }
  ],
  "until": 1333450241.741899,
  "tobj": "signals"
}
```

Application to ThereGate (in XML):

```
<event>
        <type>movement</type>
        <value>false</value>
</event>
```

Example alignments

- Motion/movement/move/…

```
<map>
  <Cell>
    <entity1 rdf:resource='http://there#motionDetectorSignal_List_Data_MotionDetected'/>
    <entity2 rdf:resource='http://app#movementDetectorResponse_Event_Movement'/>
    <relation>=</relation>
    <measure rdf:datatype='http://www.w3.org/2001/XMLSchema#float'>1.0</measure>
  </Cell>
</map>
```

```
<owl:DatatypeProperty rdf:about="http://there#motionDetectorSignal_List_Data_MotionDetected">
  <owl:equivalentProperty rdf:resource="http://app#movementDetectorResponse_Event_Movement"/>
</owl:DatatypeProperty>
```

Limitations

- Human-involvement@
  - Disambiguating ‘hard’ cases of terminology i.e. terms that have not entry in a lexicon e.g. ‘ts’
  - Validation of ontology definition alignments
- Ontology wizard
  - JSON/XML to OWL transformation
  - OWL definitions refinement (additional/better heuristics)

Plans

- an IoT Interoperability Service (IoT-IaaS) to enable the interoperation of all the different types of IoT entities in a **Plug-n-Play** fashion
- Extend SSGF tools capability to support close-to-full automation in terms of
  - Uncovering the semantics of IoT entities
  - Aligning their semantics
- Scalability
  - Experiments with large sets of devices and apps

Q&A

- Thank you!

https://www.youtube.com/watch?v=R15Xnc2-Ovs

Kotis, K., and A. Katasonov, "**Semantic Interoperability on the Internet of Things: The Semantic Smart Gateway Framework**",*International Journal of Distributed Systems and Technologies (IJDST)*, vol. 4, issue 3, pp. 47-69, 07/2013

IoT and Big Data

- IoT **needs** data
- IoT **produces** (sensors) and **consumes** (analytics) data
- Big data and the IoT are **two sides of the same coin**