SENSEI: An Architecture for the Real World Internet

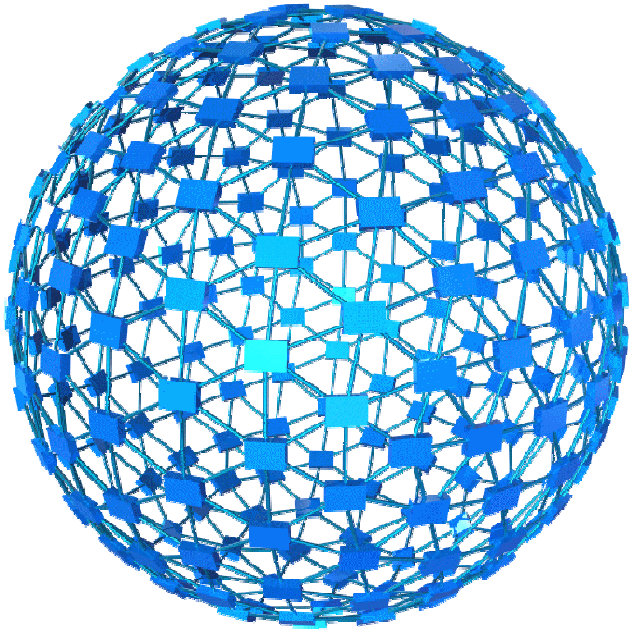
(Semantic Interoperability for RWI, Research issues and Challenges)

Presenter: Payam Barnaghi
University of Surrey

First International Workshop on
Semantic Interoperability for Smart Spaces (SISS 2010)
June 2010, Riccione, Italy

Future Internet

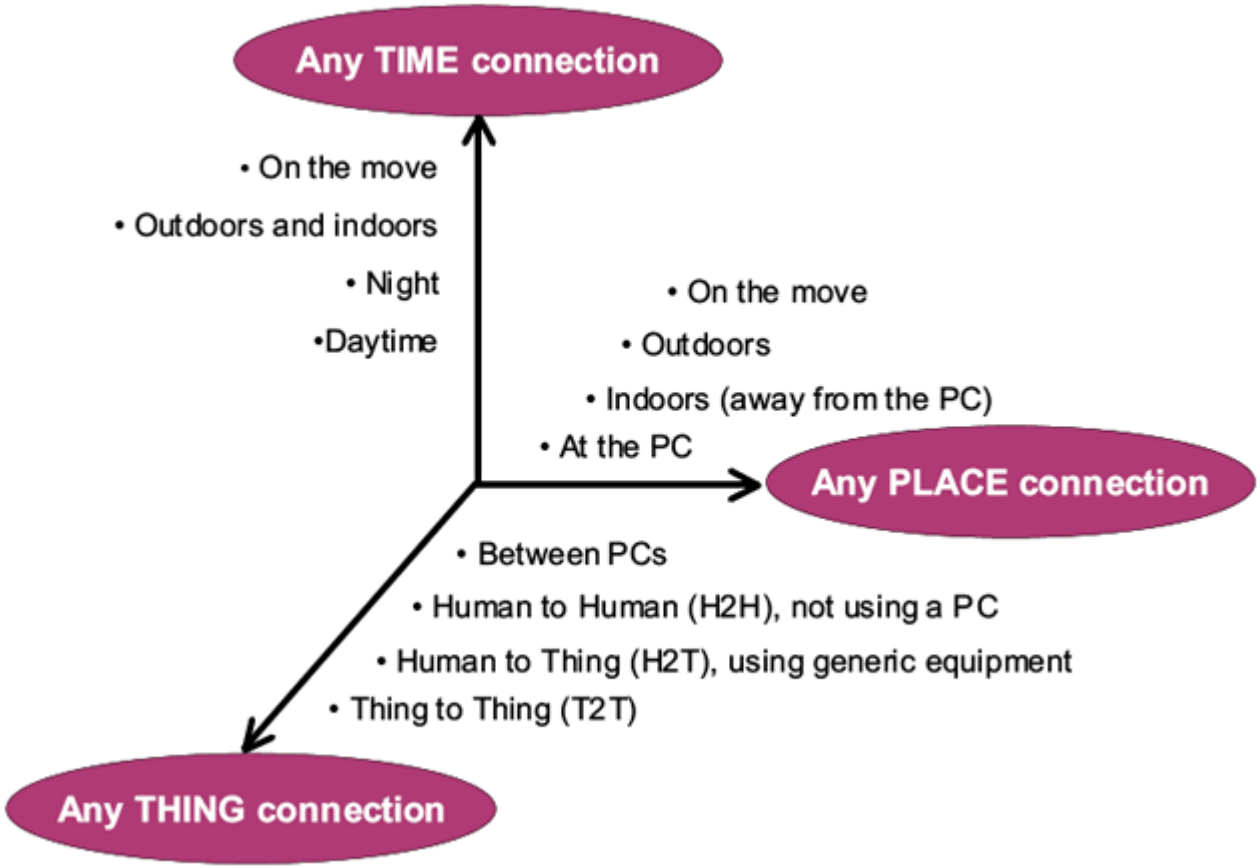
- Internet of Services
- Internet of Things
- Real World Internet
- ….



- Infrastructure changes
  - 3G, 4G
  - …
  - Sensors/actuators

- Web developments: Web 2.0 and Web 3.0

Future Internet - A new dimension



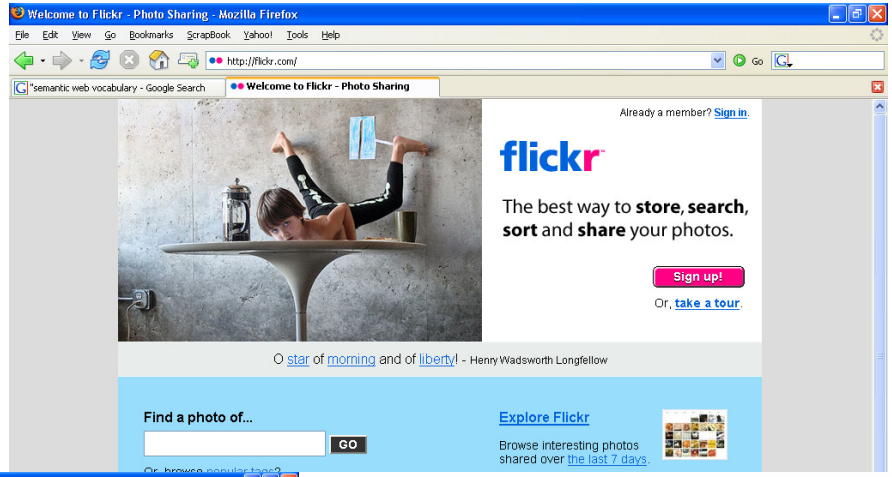
Source: ITU adapted from Nomura Research Institute

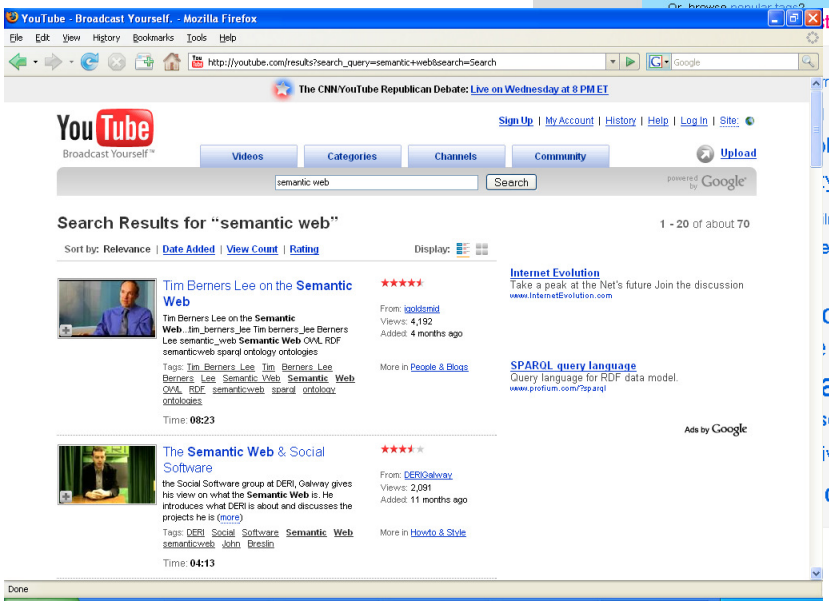
Content and Context

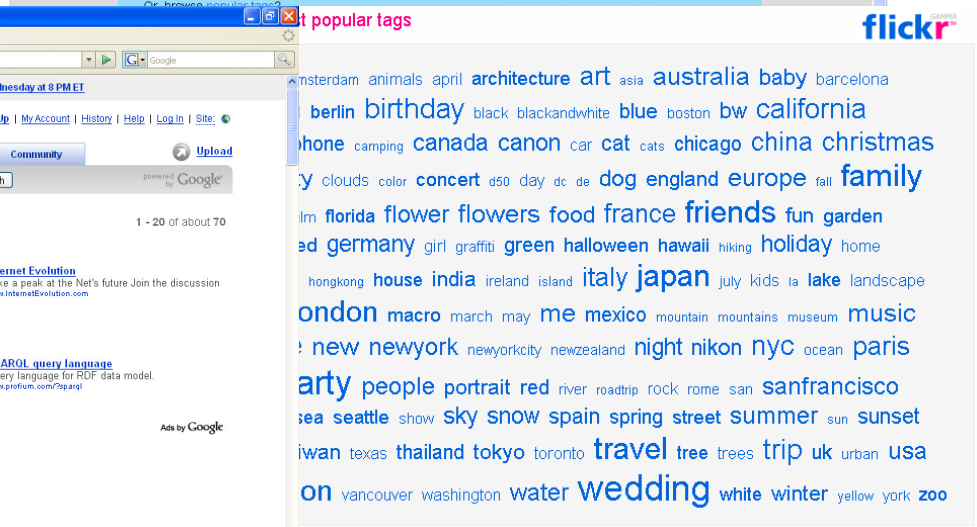
- It is all about …
  - Content?
  - Context?
- What are the Web enabler technologies
  - Syntactic Web (web of links)
  - Social Web
  - Semantic Web
  - Web of Services?
- How Internet and Web are evolving?

Content

- Documents (text-based data)
  - Hypertext
- Multimedia
  - Hypermedia
- IPTV
- …







Context

- Context could refer to a broader scope than simply spatio-temporal attributes.
- Context can be defined as information on the user*:
  - knowledge of habits
  - emotional state
  - bio-physiological conditions
  - user's social environment
    - co-location of others
    - social interaction,
    - group dynamics,
  - user's tasks
    - spontaneous activity
    - engaged tasks
    - general goals;

[Image source: Albrecht Schmidt]

* Albrecht Schmidt, Michael Beigl and Hans-W. Gellersen (December 1999). "There is more to Context than Location", Computers & Graphics Journal, Elsevier 23 (6): 893-902

Perception and context enables smart behaviour

- Perception in Nature
  - Adaptation to the environment
  - Foundation for intelligent behaviour
  - Acting and reacting in an appropriate way
- Sense is more than sensor – the whole process
  - reception of the stimulus
  - translation from stimulus to signal
  - signal transport
  - the processing/matching on several levels
- Different senses
  - Vision, Hearing, Smell, Taste, Touch, Temperature
  - Gravity and acceleration, Position and constellation of (body) parts

[Slide is adapted from: Albrecht Schmidt, Context-Aware Communication and Interaction, Tutorial at Mobile HCI 2008]

How to add the real world sense/ interactions to the digital world?

Current status

- Large-scale Sensor/Actuator networks (will) enable connecting millions of resources in a global scale.
- The sensor resource provide observation and measurement data from the real world.
- The current data transmission on sensor networks mostly relies on binary or syntactic data models which lack of providing machine interpretable meanings to the data.
  - Binary representation or in some cases XML-based data
  - No general agreement
  - Requires an pre-agreement on both communication parties to be able to process and interpret the data
  - Limited reasoning
  - Limited interoperability
  - Data integration and fusion issues

How far are we from real world awareness?

- Enabling technologies already maturing
  - Sensor and actuator networks
  - Data fusion and classification, inference/reasoning and machine learning
  - Distributed service composition and semantic web technologies

- Key is to combine these technologies into a homogeneous fabric for real world information and interactions
  - Provide an easily accessible resource pool in which Internet applications and services can tap in to interact with the real world
  - Enable an open market space around it for real world information and interactions

What we need in service/application level?

- Homogenous access to data
  - a universal language and at the same time an open framework
- Deriving additional knowledge (data mining)
  - Supporting advanced analytics of archived data
- Reusable knowledge
- Granularity of information
  - accessing the information based on different levels of detail (e.g. all temperature data from office building;/ temperature data for room U8)
- Self-descriptive data (sensor network is a generic heterogeneous environment)
- Supporting high-level rule definition (logical reasoning) (e.g. high temperature + smoke =>fire

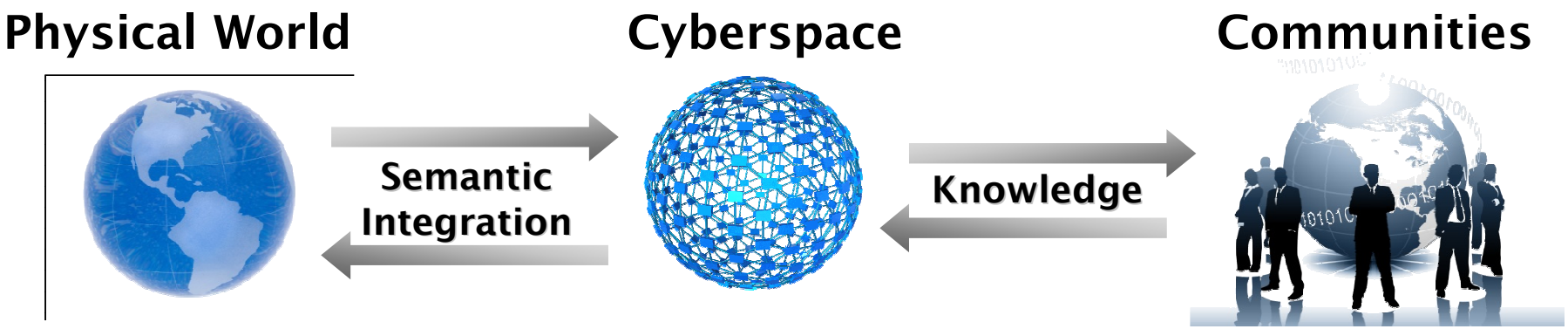
Sensor Data on the Web?

- Bringing Sensor Information to the same level as document*
  - i.e. connecting the real with the digital world
- Sensor information as web documents
- Web annotations and associating the descriptions to existing ontologies
  - Focusing on existing standards such as those provided by W3C, and OGC
  - Linked-data approach
- Sensor data like Linked-data

Vision

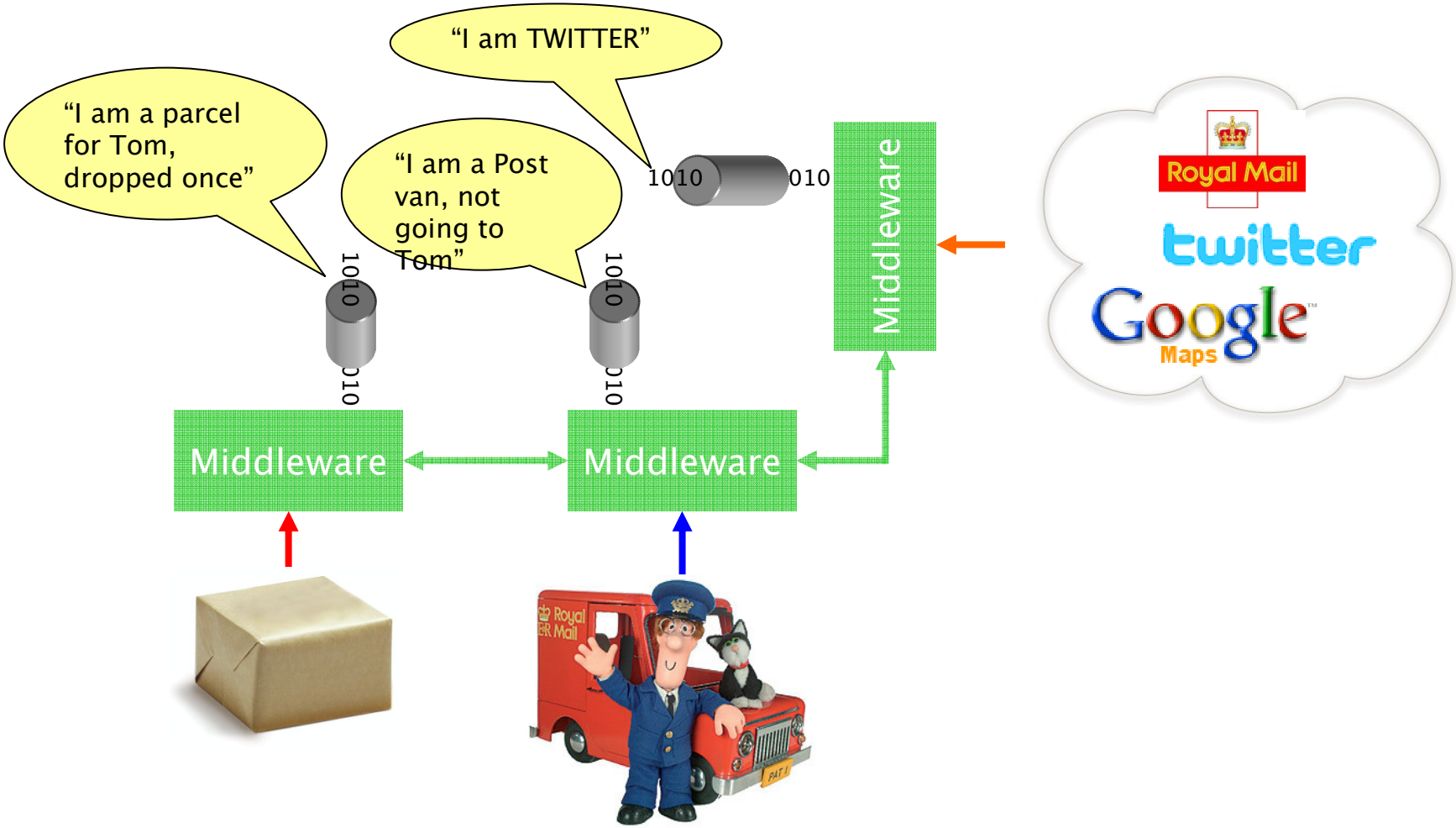
- Integration of millions of interconnected resources
- Bridging the gap between real world and the logical world
- Annotating resources and emerging data
- Mediating information flow between real world resources (things) and high-level applications and services
- Reasoning services and creation of a networked knowledge
- Semantic advertisement of data/service

Bridging the gap



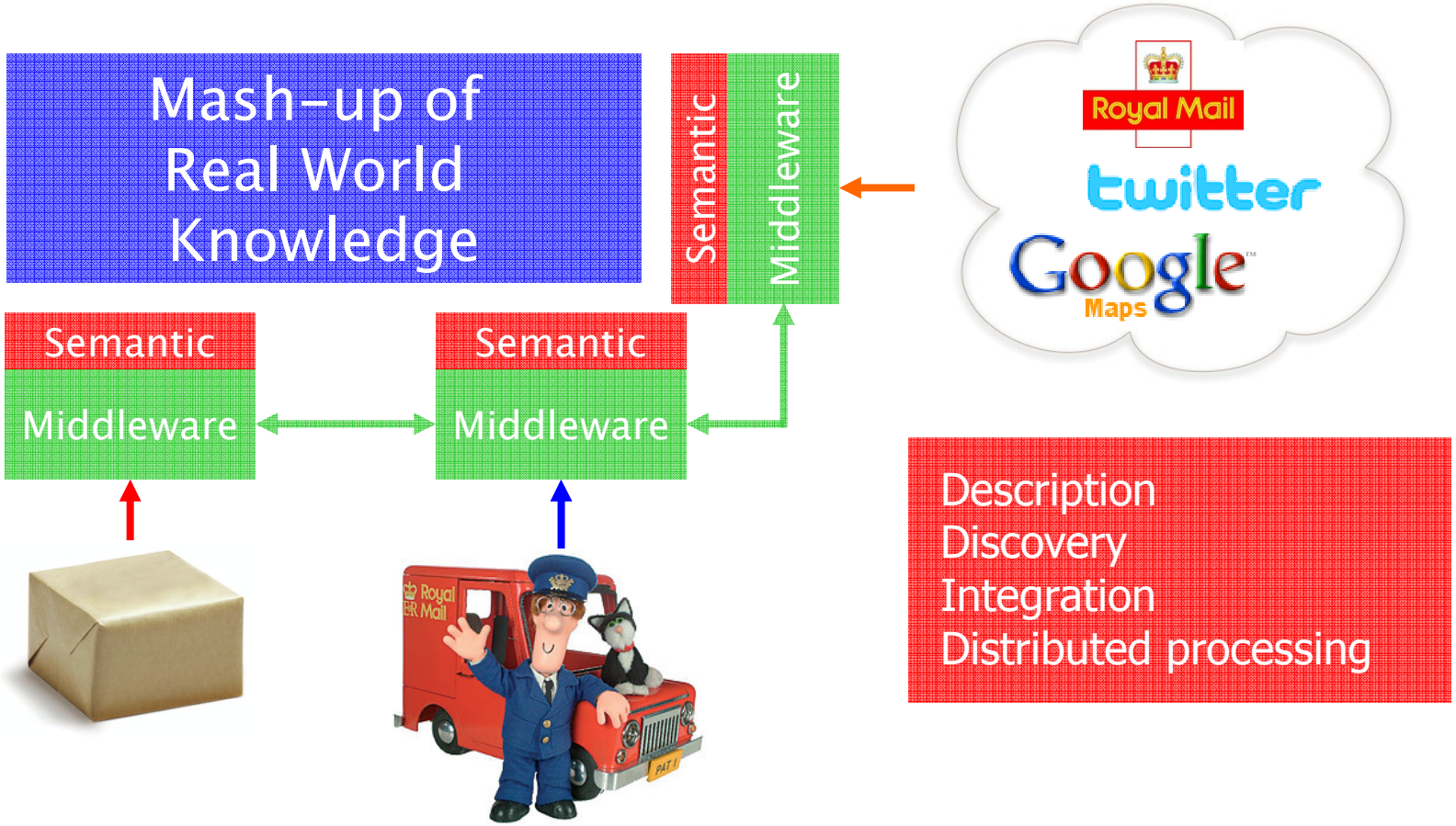
Making sensor-generated information usable as a new and key source of knowledge will require their integration into the (existing) information space of Communities → Semantic Integration

Semantic integration- example



[Prasad, 2009]

Semantic integration- example



[Prasad, 2009]

How to do all these? What do we need?

The Real World Internet

- The next revolution of the Internet is the complete manifestation of the real world in digital format.

THE REAL WORLD INTERNET

- infrastructure that enables augmentation of and interaction with the physical world
- composed out of an endless number of sensors and actuators connected to the Internet
- information is well described and available so that it can be composed and used by other systems, applications and services.

Properties of a Real World Internet

- Numbers of devices and users
  - Orders of magnitude larger, shift of users from human to machine
  - Challenge: Scalability
- Heterogeneity of edge devices
  - Increase in diversity
  - Challenge: Ease of interoperability
- Information explosion and privacy
  - Increase in amount of generated information and ways of its representation
  - Challenge: Enabling unified and controlled access

Properties of a RWI

- Growing importance of meta-data
  - Information has to be put in right context to enable processing of it
  - Ratio of meta data to information much larger
  - Challenge: Unified description of metadata and its efficient association

- Freshness of information
  - Data may be much more ephemeral
  - Amount of generated information calls for new caching strategies
  - QoS support in network for real time may be justified
  - Challenge: Information management and real time support

Properties of a RWI

- Information flows and traffic patterns
  - More complex information flows, end-to-end assumption may no longer work
  - New traffic patterns, driven by real world events
  - Challenge: Minimise impact on network infrastructure

- Mobility
  - New forms of mobility beyond traditional models
  - Example – Mobility of real world entities
  - Challenge: Maintain service continuity for new forms of mobility

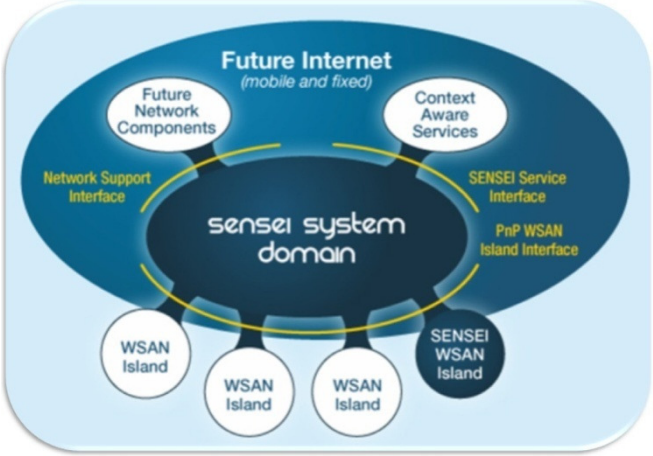
SENSEI Architecture - overview

The SENSEI Project at a Glance

About SENSEI

- SENSEI is the biggest Integrated Project in the EU's Seventh Framework Programme ICT, from Call 1, Challenge 1.1: The Network of the Future.
- The main goal of SENSEI is to integrate the physical with the digital world of the network of the future.
- Behind the concept of SENSEI is the idea of sensors, actuators, and efficiently networked nodes deployed everywhere and interconnected. They are accessible and manageable through a global and pluggable sensor and actuator networking framework.

Architecture



Objectives

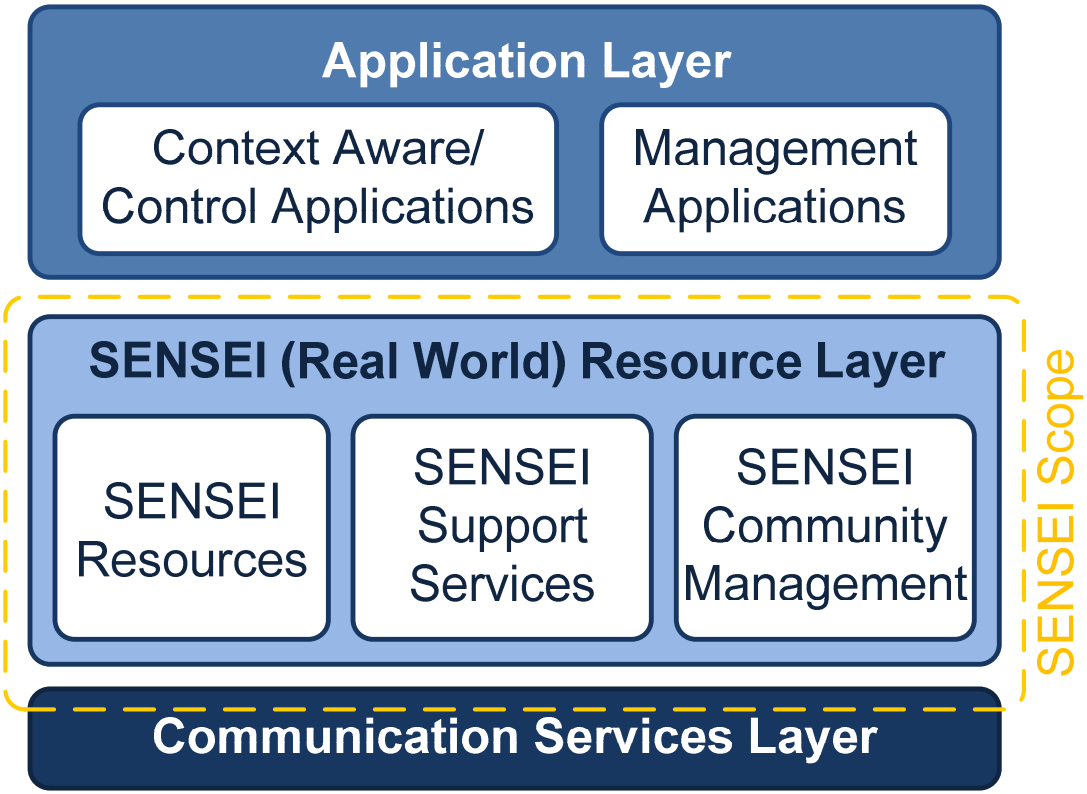
- Support a large number of WSANs, through a plug and play WSANs interface
- Be an enabler of applications, that process sensor data and its context information, via the SENSEI service interface
- Allow the connection of present and future networks, via the network support interface

Partners

Design considerations

- Inspired by service oriented architecture
  - Loosely coupled interactions, service composability, service discoverability
- Enable multiple context frameworks on top of unifying sensor framework
  - Support horizontalisation across multiple application domains, without compromising flexibility required for domain specific context
  - Unifying abstraction for sensor, actuator and processing resources
- Support the heterogeneity of resources through openness
  - Unified resource descriptions not resource access interfaces
- Design for evolution of the architecture
  - Decoupling of resource layer from applications and underlying communication substrate
  - Modular design of service functions, interfaces that enable choice at runtime

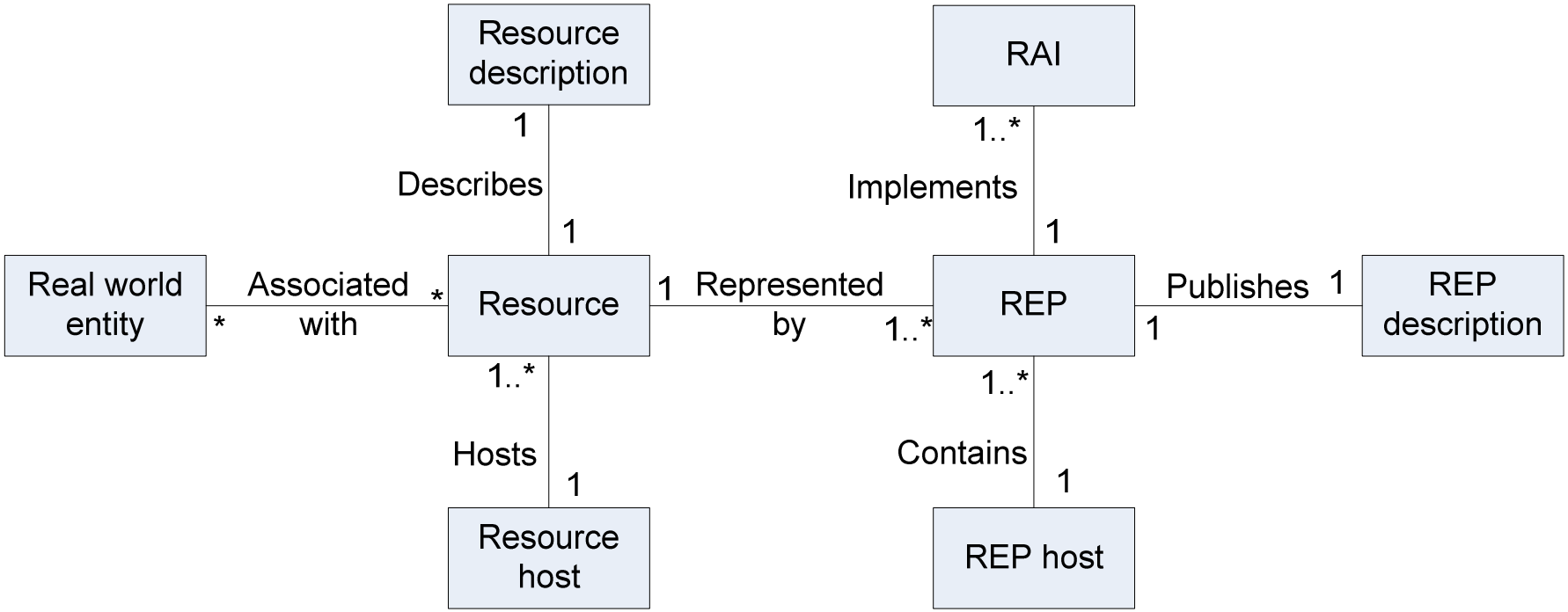
High level overview



Resource concept

- Resource is a conceptual representation in the SENSEI domain
  - any information source that can provide real world information
  - any interaction capability with the real world
- Modelling the Resources and representing them using machine-interpretable specification allows:
  - Interoperability
  - Seamless integration of sensing/actuation resources

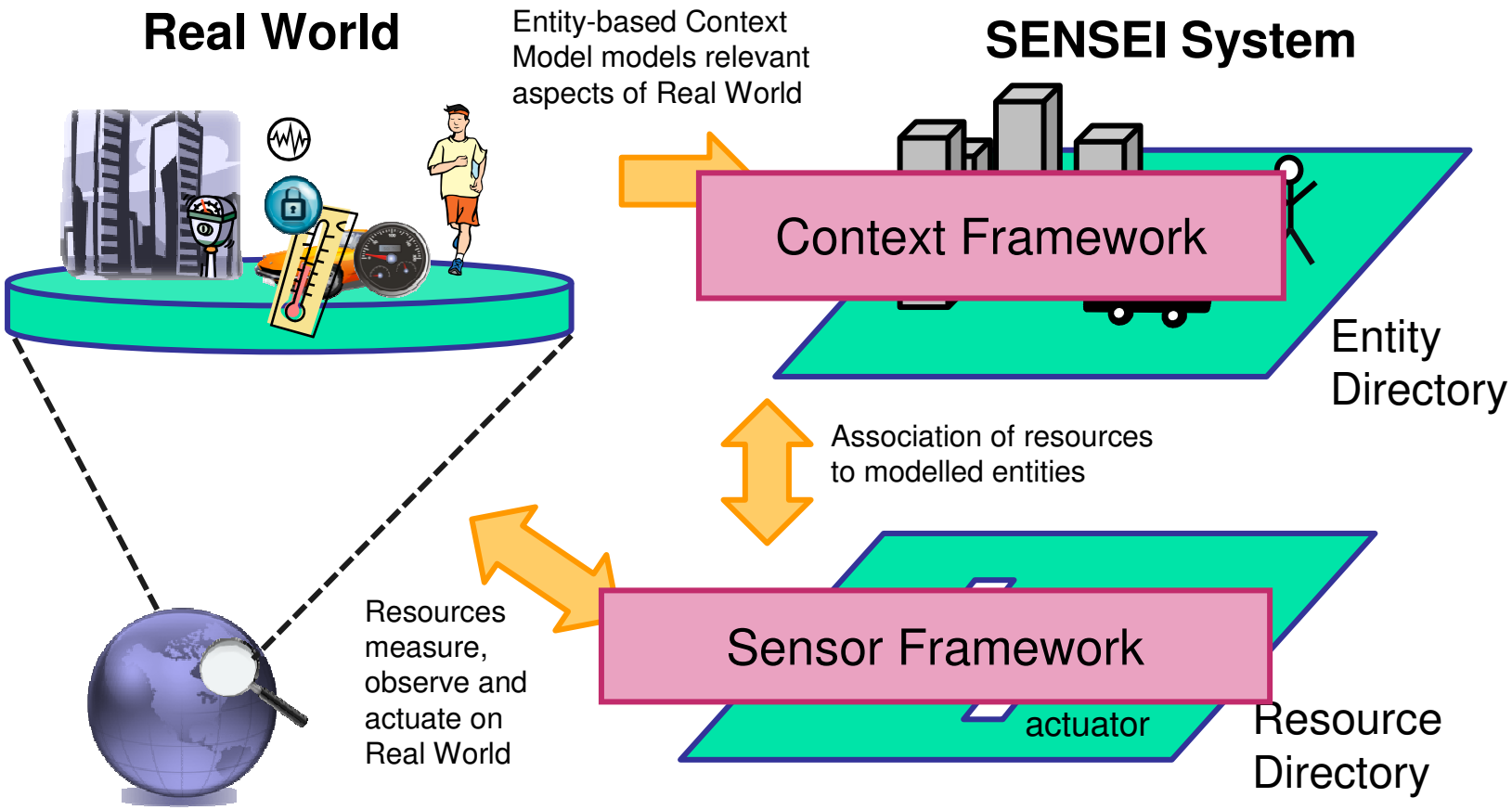
Resources in SENSEI



Resources in SENSEI

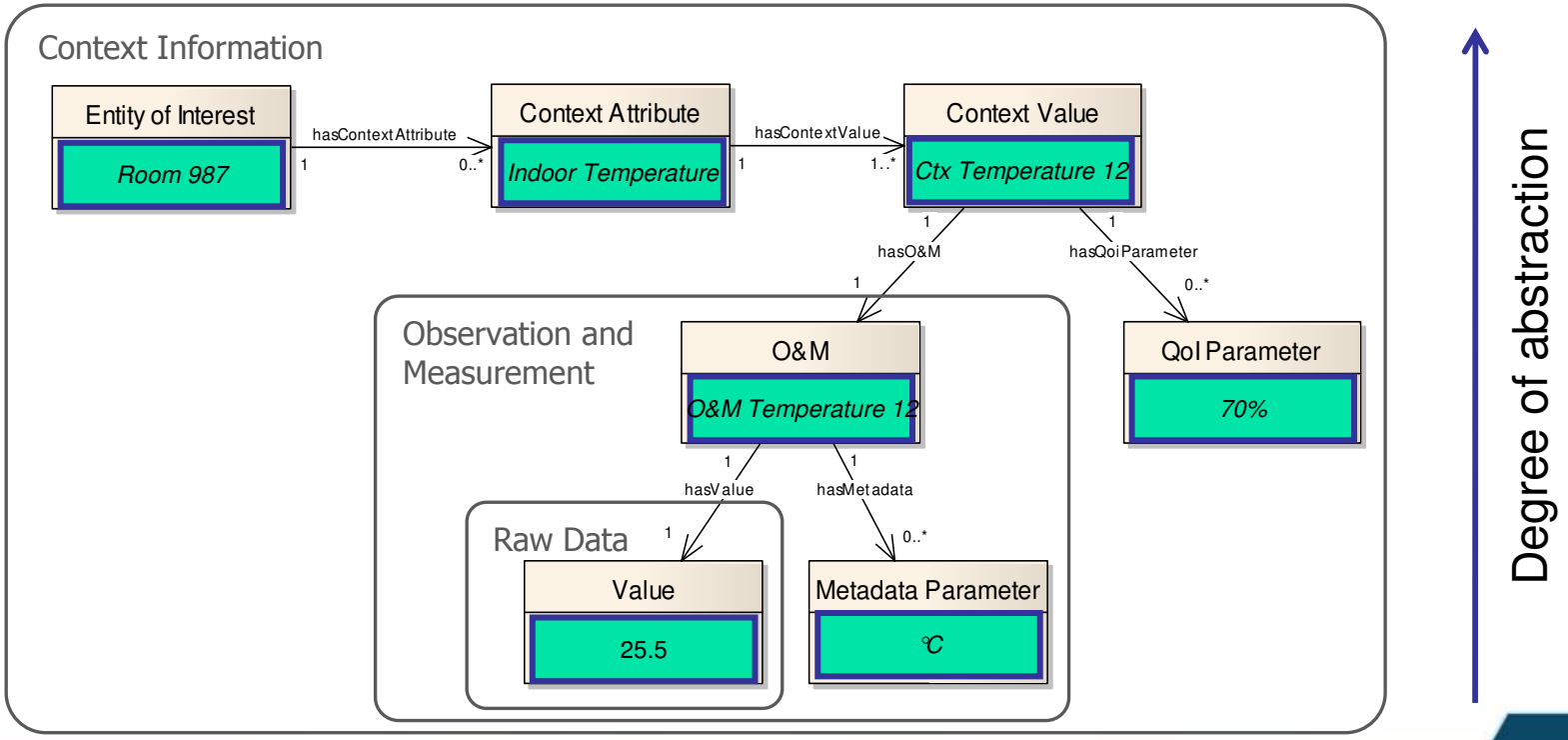
- Semantic models for:
  - Resource description (sensei)
  - Entity description (sensei)
  - Entity associations to external world (not sensei)
  - Context model (sensei)
  - Context reference to domain knowledge (not sensei)
  - Resource Access Interface
    - Service-oriented description

Modelling and Interactions

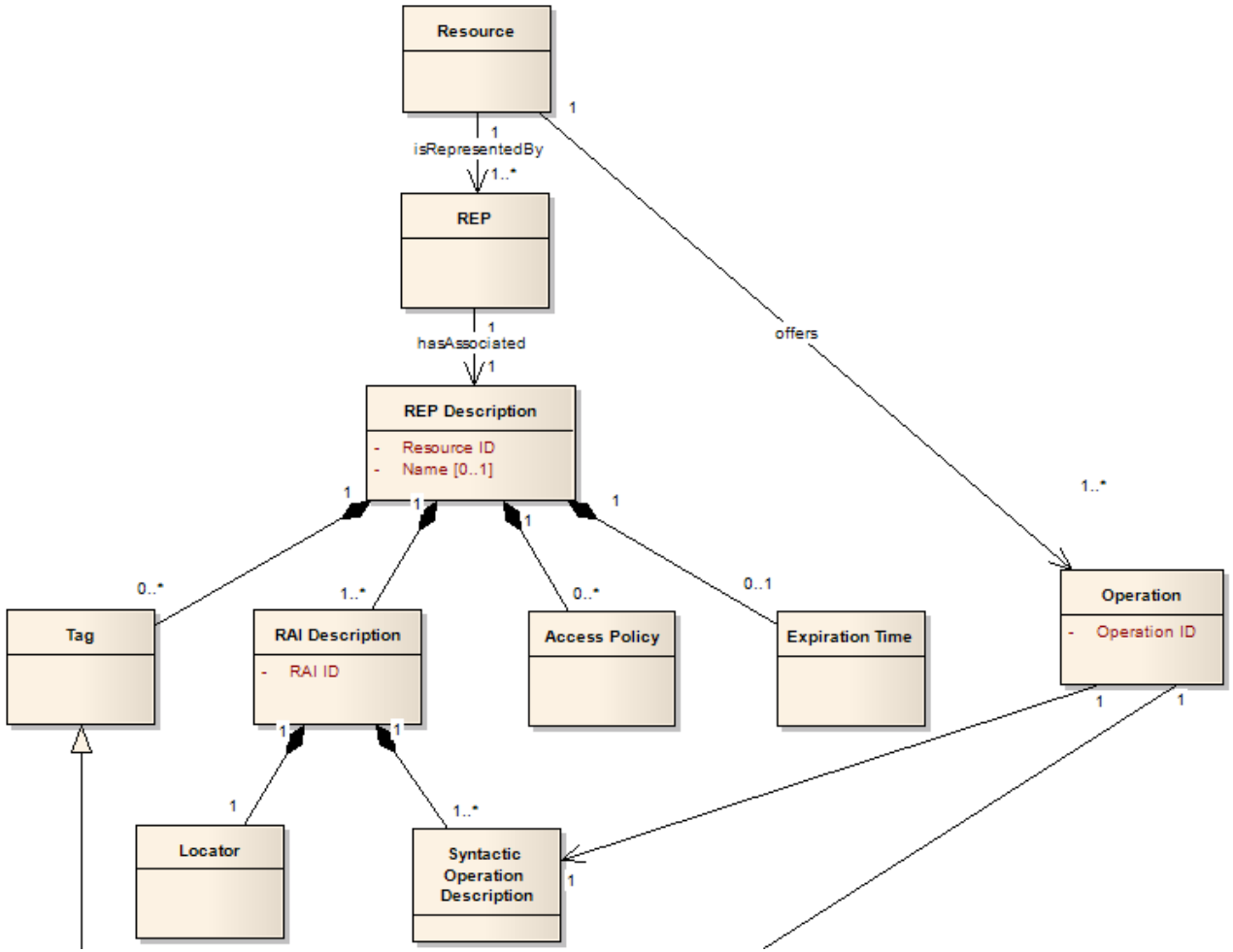


Context Framework on top of Sensor Framework

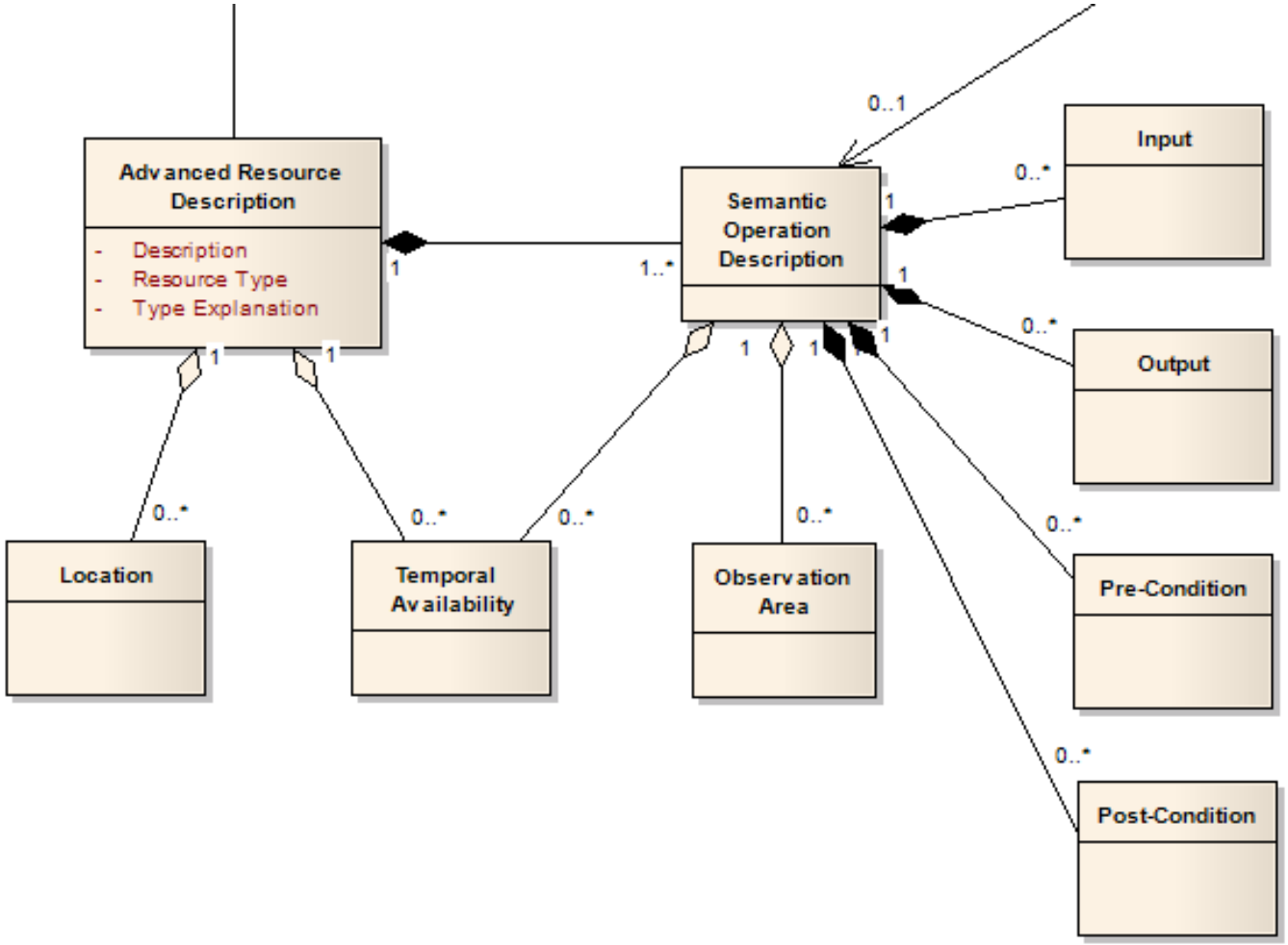
- **Three-level information modeling:**
  - raw data (physical sensor)
  - observation & measurement (resource)
  - entity-based context-information (advanced components/resource)



Basic resource description



Advance Resource description

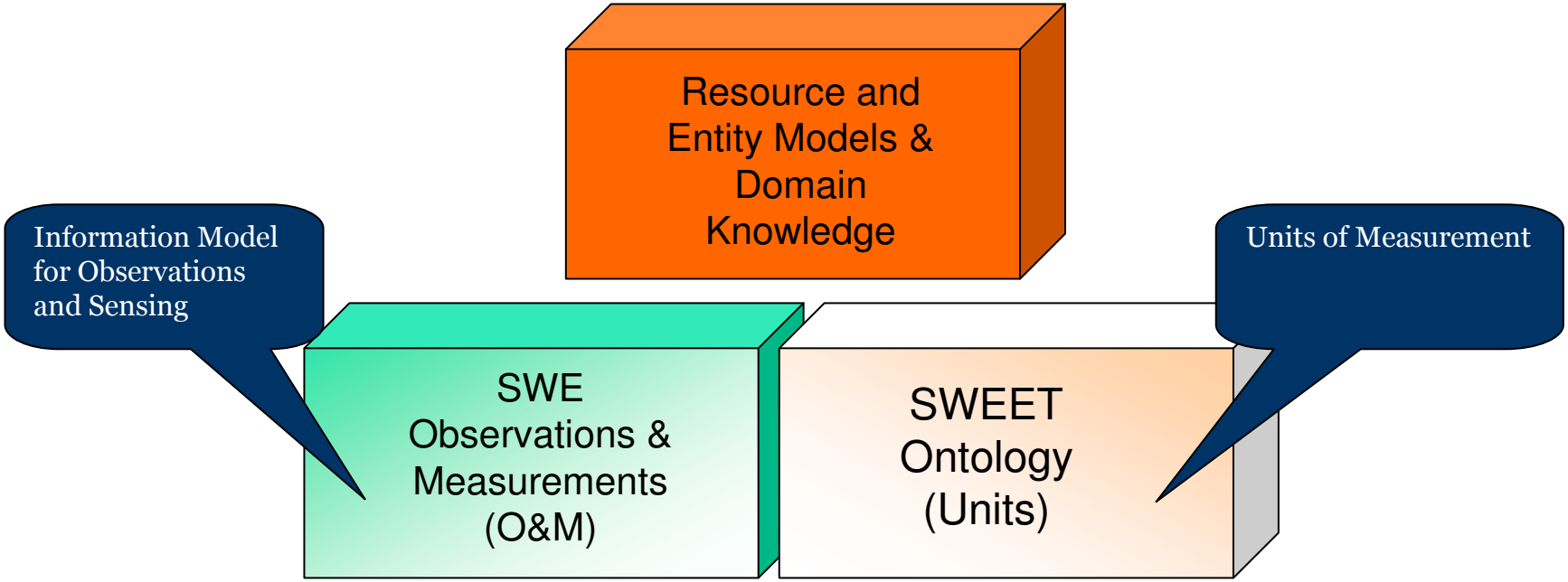


Entities of interest

- An entity provides a handle to any physical or virtual thing to be represented in the system
  - Examples for entities are persons, places, or objects that are considered relevant for providing a service to users
- An entity can be uniquely identified and is described through properties
- Queries for context information and actuation typical relate to one or more entities -> Entities of Interest
- The system has to know what resources are available to provide context or actuation concerning entities of interest

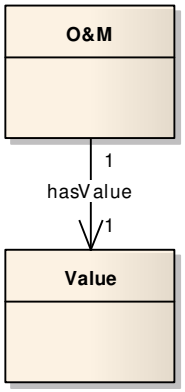
Observation and Measurement

- Based on SWE Observation & Measurement
- NASA's Sweet ontology

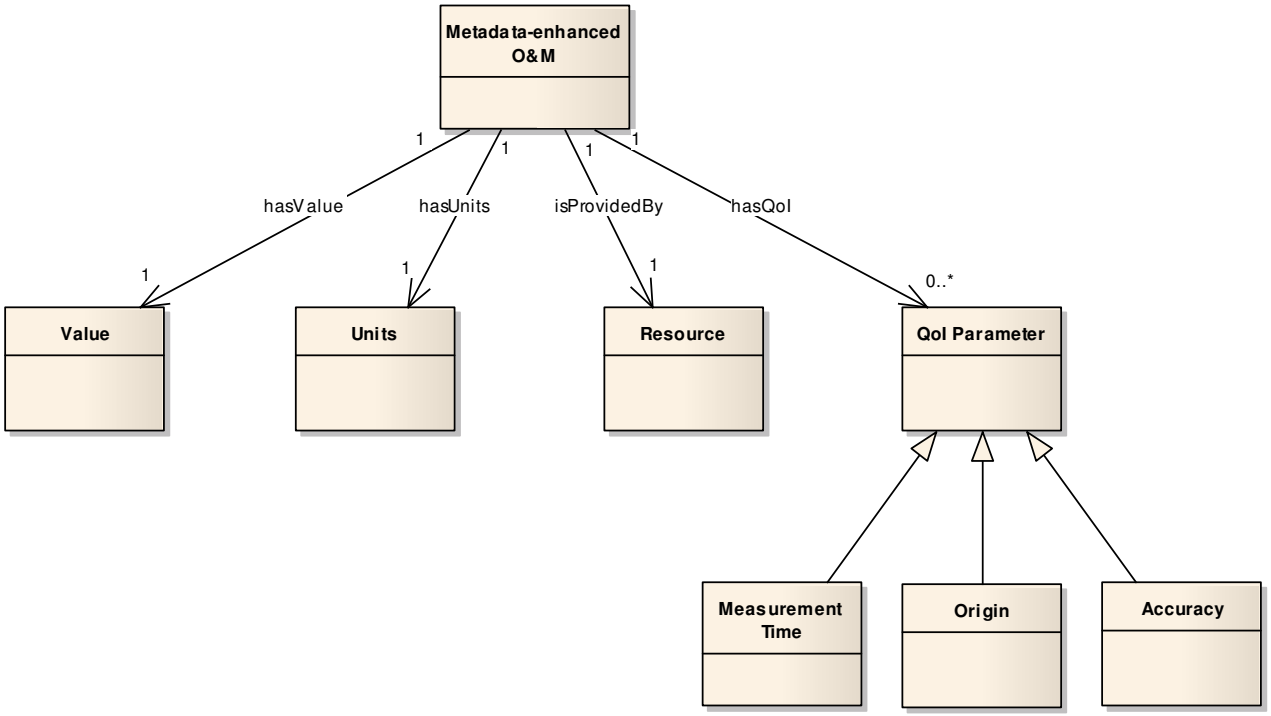


O&M Information model

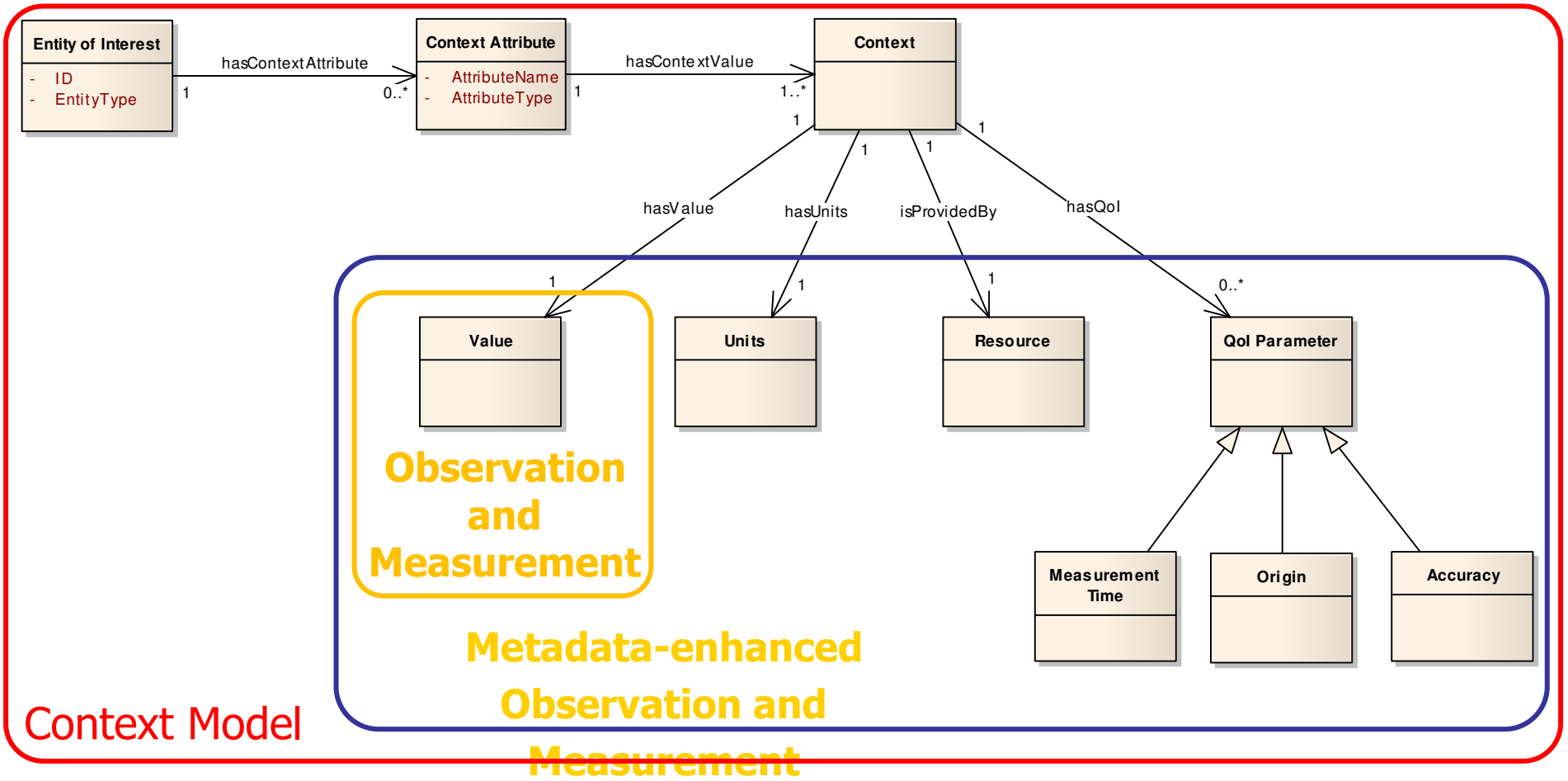
- Observation and Measurement



- Metadata-enhanced Observation and Measurement

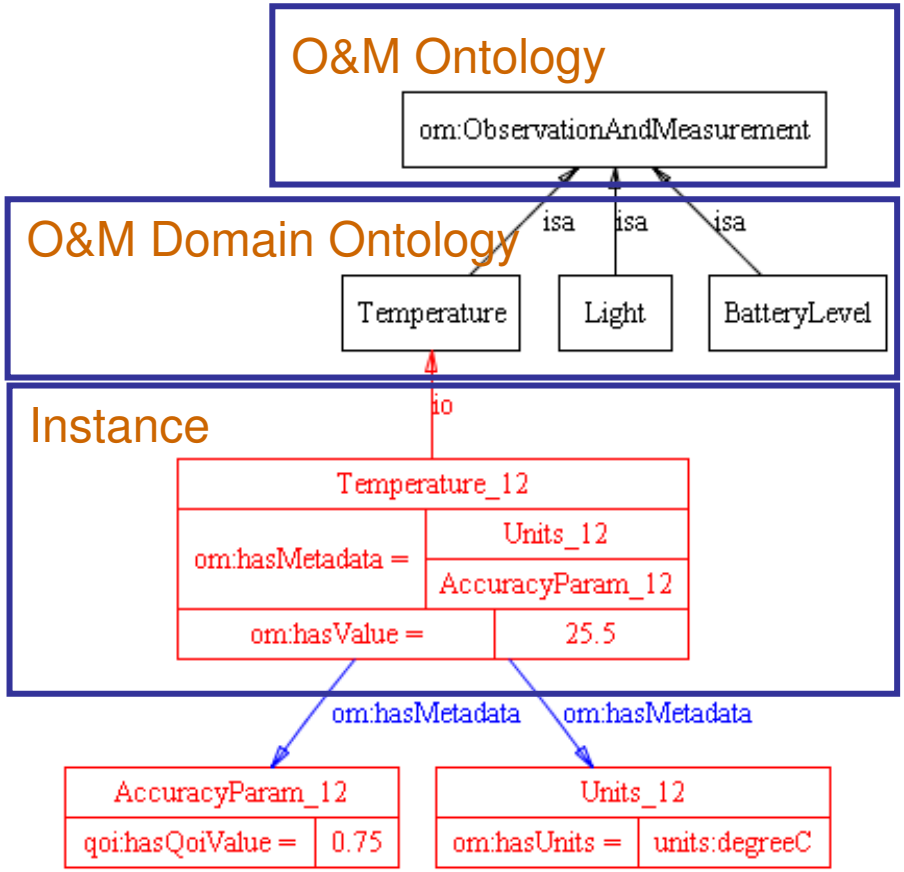


SENSEI Information Model



Example of an O&M

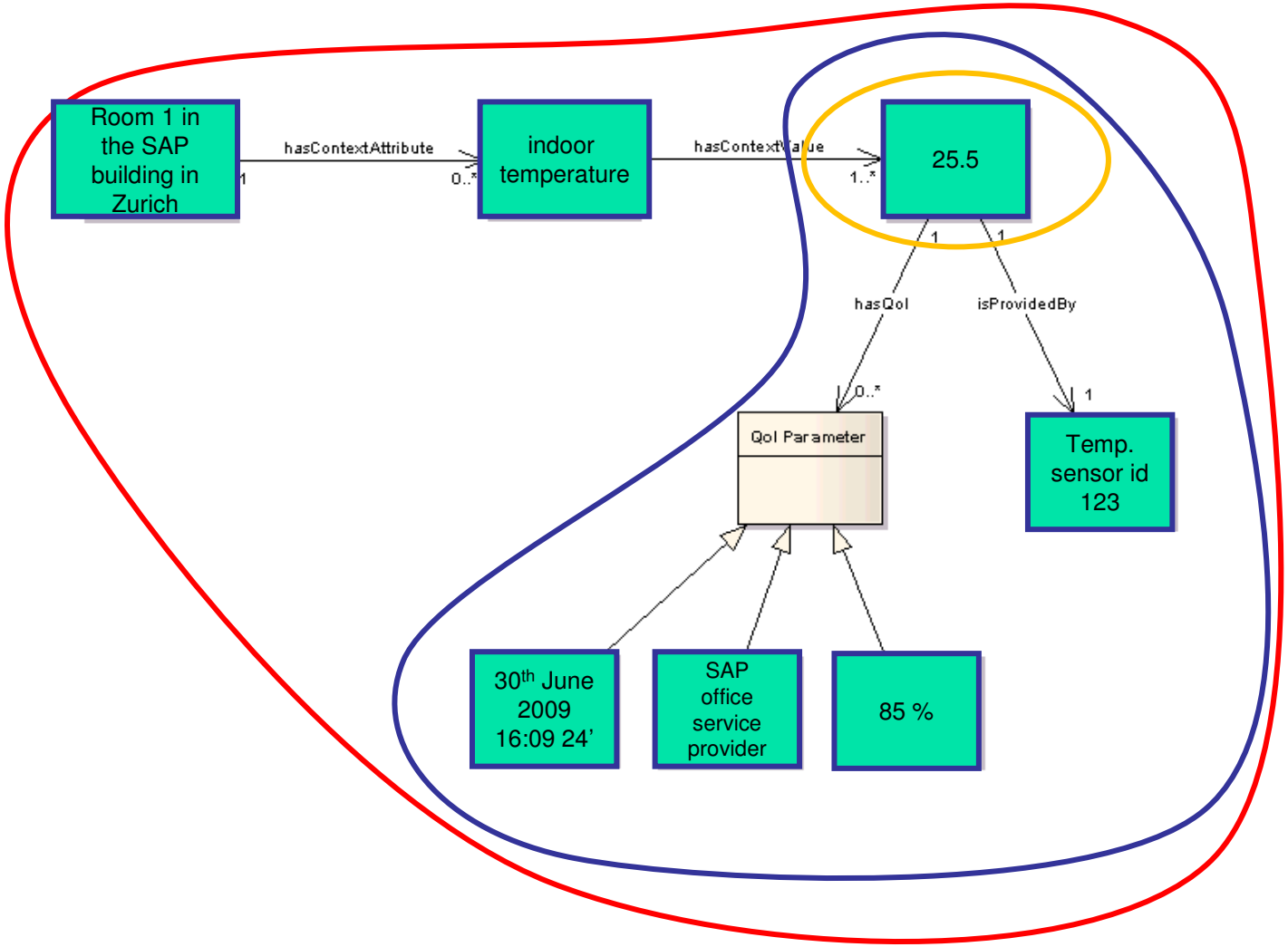
- RDF-based representation providing basis for semantic interpretation
- Modular approach: Different domain data coexist without having to interact.
- Easily extensible to future needs by creating new domain ontologies extending the Information Model



Sample O&M in RDF

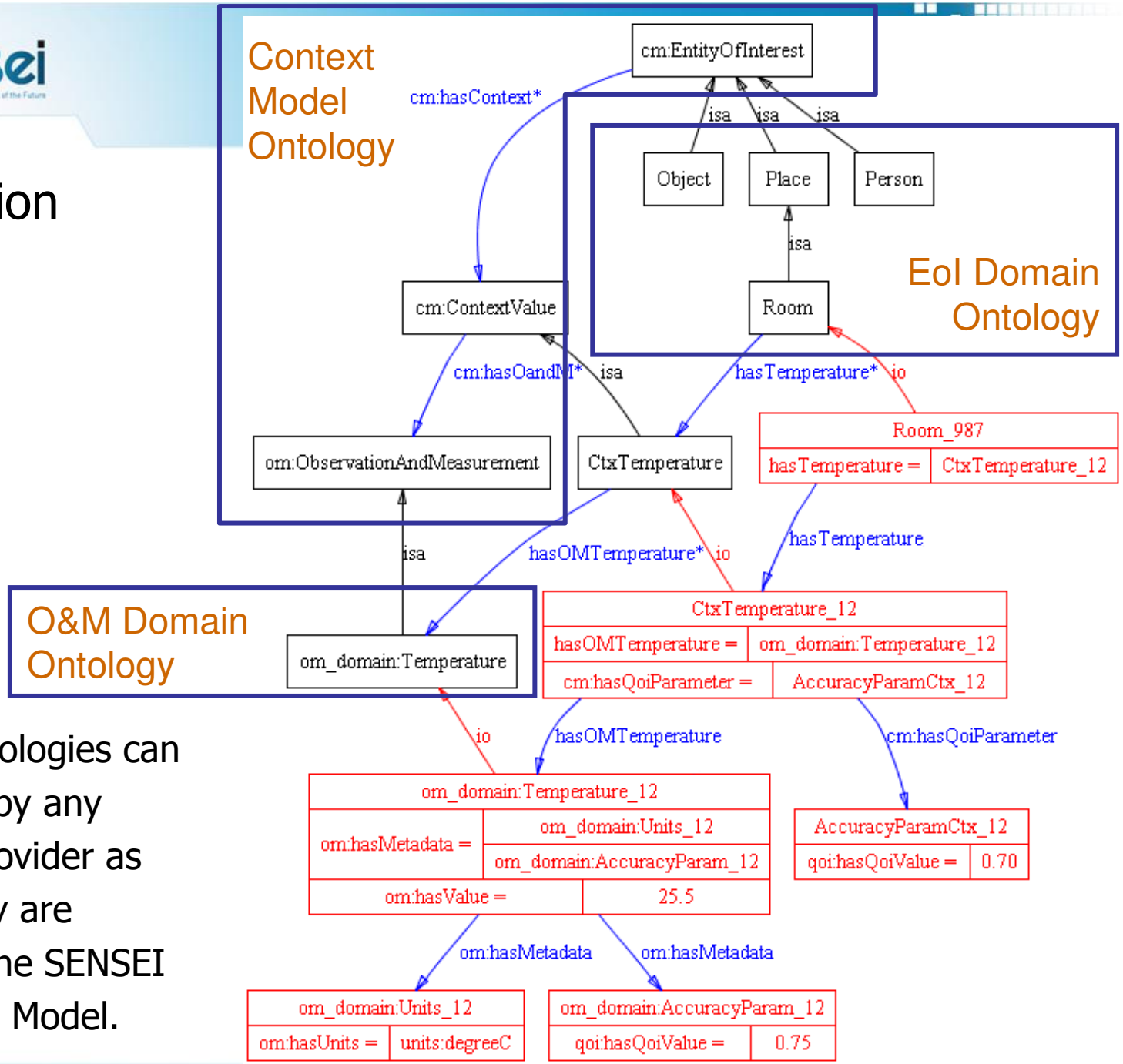
```
<swe-om:Quantity rdf:ID="Quantity_AirTemperature">
    <swe-om:hasUomIdentifier rdf:resource=
        "http://sweet.jpl.nasa.gov/ontology/units.owl#degreeC"/>
    <swe-om:hasDoubleValue rdf:datatype="http://www.w3.org/2001/XMLSchema#double"
    >35.1</swe-om:hasDoubleValue>
    <swe-om:hasName xml:lang="en">air temperature</swe-om:hasName>
    <swe-om:hasDefinition rdf:datatype="http://www.w3.org/2001/XMLSchema#anyURI"
    >urn:ogc:def:property:OGC:AirTemperature</swe-om:hasDefinition>
</swe-om:Quantity>
<swe-om:Quantity rdf:ID="Quantity_WindSpeed">
    <swe-om:hasDefinition rdf:datatype="http://www.w3.org/2001/XMLSchema#anyURI"
    >urn:ogc:def:property:OGC:Windspeed</swe-om:hasDefinition>
    <swe-om:hasName xml:lang="en">wind speed</swe-om:hasName>
    <swe-om:hasUomIdentifier rdf:resource=
        "http://sweet.jpl.nasa.gov/ontology/units.owl#meter_perSecond"/>
    <swe-om:hasDoubleValue rdf:datatype="http://www.w3.org/2001/XMLSchema#double"
    >6.5</swe-om:hasDoubleValue>
</swe-om:Quantity>
<swe-om:DataRecord rdf:ID="DataRecord_AtmosphericConditions">
    <swe-om:hasField rdf:resource="#Quantity_AirTemperature"/>
    <swe-om:hasField rdf:resource="#Quantity_WindSpeed"/>
    <swe-om:hasDefinition rdf:datatype="http://www.w3.org/2001/XMLSchema#anyURI"
    >urn:ogc:def:property:OGC:atmosphericConditions</swe-om:hasDefinition>
</swe-om:DataRecord>
```

Another O&M Example



- Observation and Measurement
- Metadata-enhanced Observation and Measurement
- Context Model

Context Information

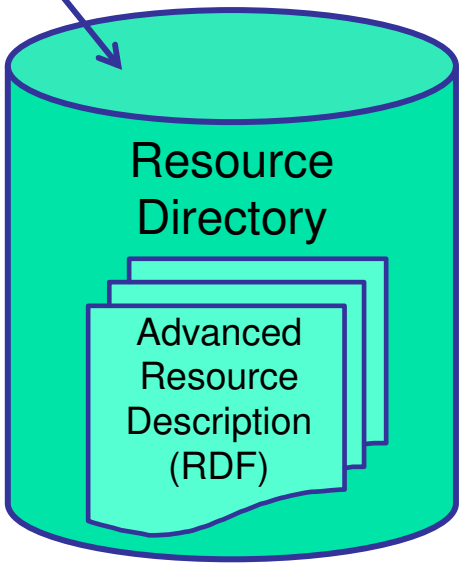


- Domain ontologies can be defined by any resource provider as long as they are extending the SENSEI Information Model.

ARD Lookup: Temperature Sensor (CFR)

Resource Request

```
<requestResource>
  <resourceSpecification/>
</resourceSpecification>
  <AdvancedSpecification>
    SELECT ?description
    WHERE { ?description ard:hasSemanticOperationDescription ?operation .
    ?operation ard:hasOutput ?output .
    ?output ard:hasInformationType ?infoType .
    ?infoType rdfs:subClassOf om:Temperature .}
  </AdvancedSpecification>
</requestResource>
```



Advanced Resource Description

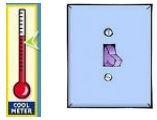
Operation: getTemp

Output: Temperature

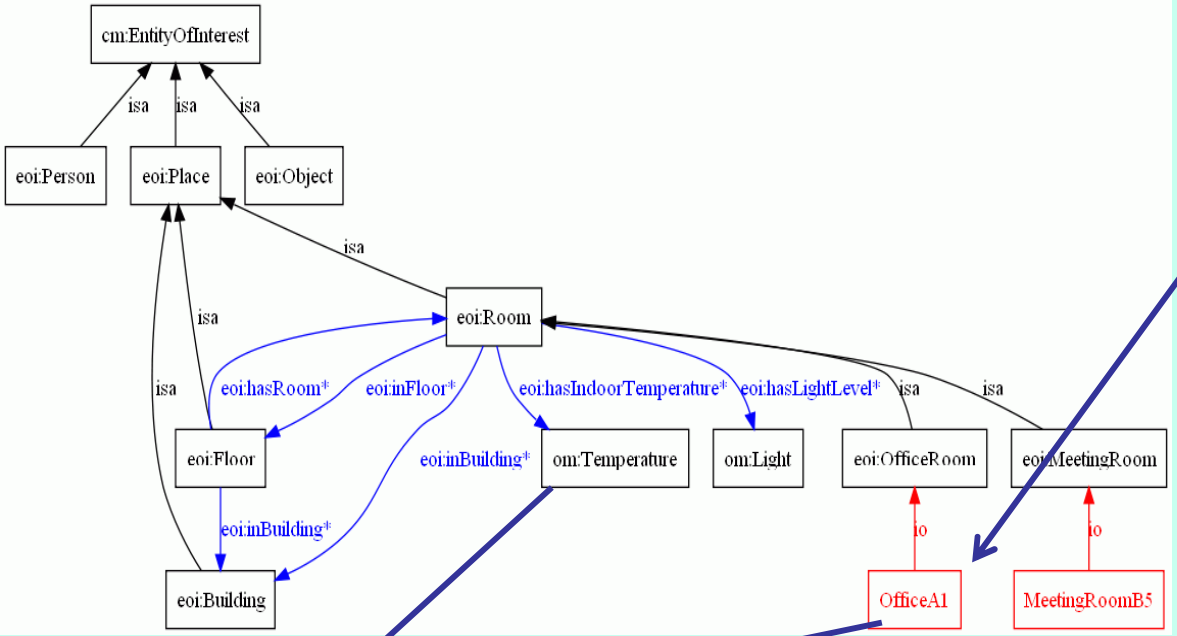
Resource Description

```
<Resource-Description>
  <Resource-ID>urn:sensei:unipd.it:Telosb:temp:0000-0000-fffe-00c7</Resource-ID>
  <Name>Temperature sensor</Name>
  <Expiration-Time>10-03-26T10:14:52+00:00</Expiration-Time>
  <Tag>urn:sensei:wsan:Padova</Tag>
  <Tag>urn:sensei:node:0000-0000-fffe-00c7</Tag>
  <Tag>urn:sensei:resourcetype:regular</Tag>
  <Tag>
    <!DOCTYPE rdf:RDF [  <!ENTITY id 'urn:sensei:unipd.it:Telosb:temp:0000-0000-fffe-00bf#'>]>
    <rdf:RDF xmlns:rdf="&rdf;"  xmlns:om="&om;"  xmlns:res="&res;"  xmlns:ard="&ard;"  xmlns:rdfs="&rdfs;"  xmlns:id="&id;">
      <ard:AdvancedResourceDescription rdf:about="&id;ARD">
        <ard:hasResourceType rdf:resource="&res;Sensor"/>
        <ard:hasSemanticOperationDescription rdf:resource="&id;Op:getTemp"/>
      </ard:AdvancedResourceDescription>
      <ard:SemanticOperationDescription rdf:about="&id;Op:getTemp">
        <ard:hasOutput rdf:resource="&id;Op:req_value-Out:1"/>
      </ard:SemanticOperationDescription>
      <ard:Output rdf:about="&id;Op:req_value-Out:1">
        <ard:hasInformationType rdf:resource="&om;Temperature"/>
      </ard:Output>
    </rdf:RDF>
  </Tag>
  <Rai-Description>
    <RAI-ID>0</RAI-ID>
    <Document-Link>urn:sensei:rai:sensor</Document-Link>
    <REP-Locator>http://sensei-cfr.broker.freenet6.net:8000/0000-0000-fffe-00c7/s/temp</REP-Locator>
  </Rai-Description>
</Resource-Description>
```

Entity directory: EoIs and mappings to resources

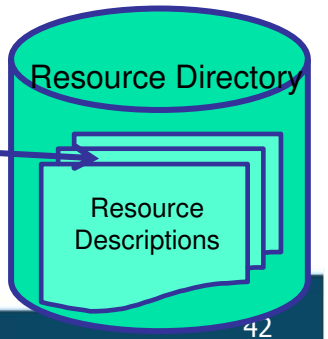


Ontology, Entity repository



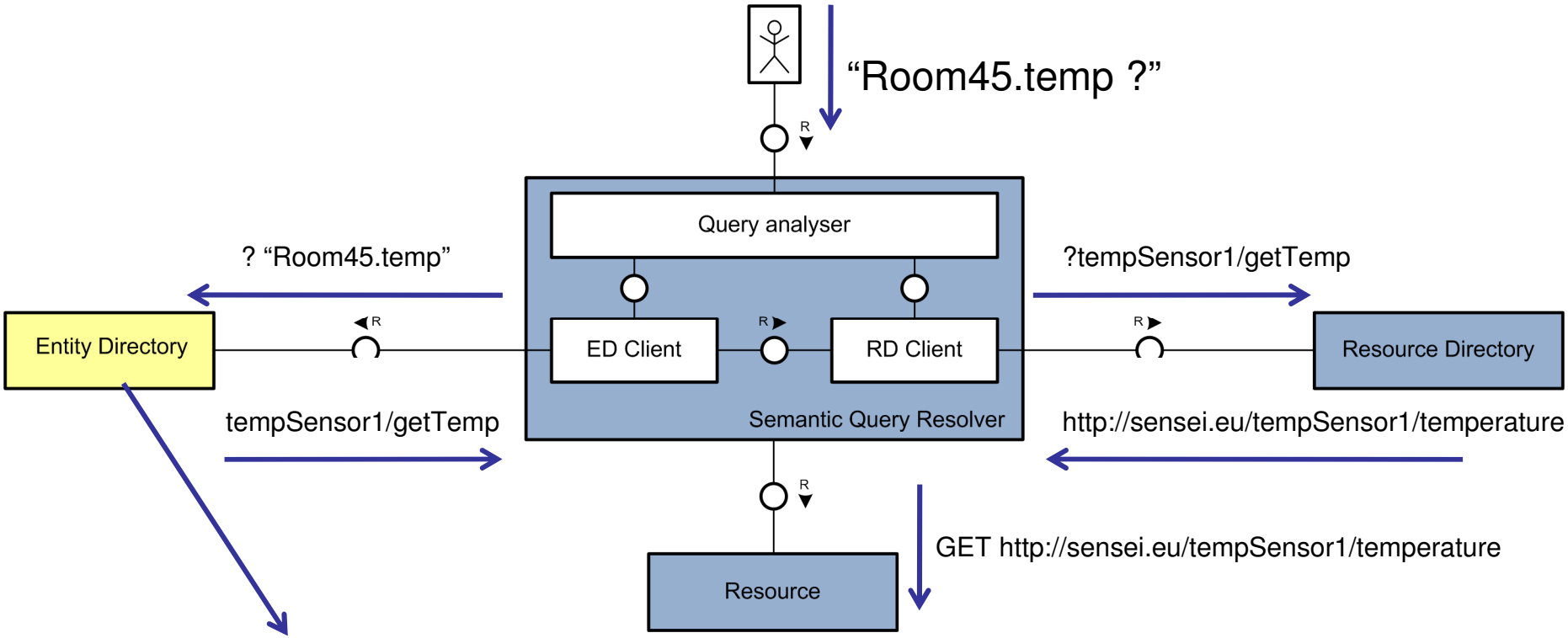
Mappings attributes / resources

Entity	Attribute	Res ID	Operation ID	Input	Output	Pre-Condition	Post-Condition
OfficeA1	**eoi:hasIndoorTemp**	**Sensor 1**	**getTemp**	**-**	**Temp**		
OfficeA1	**eoi:hasLightLevel**	**Switch 5**	**turnLightOn**	**-**	**-**	**Room45.light=off**	**Room45.light=on**
OfficeA1	**eoi:hasLightLev**	**Switch**	**turnLightO**	**-**	**-**	**Room45.light=**	**Room45.light**



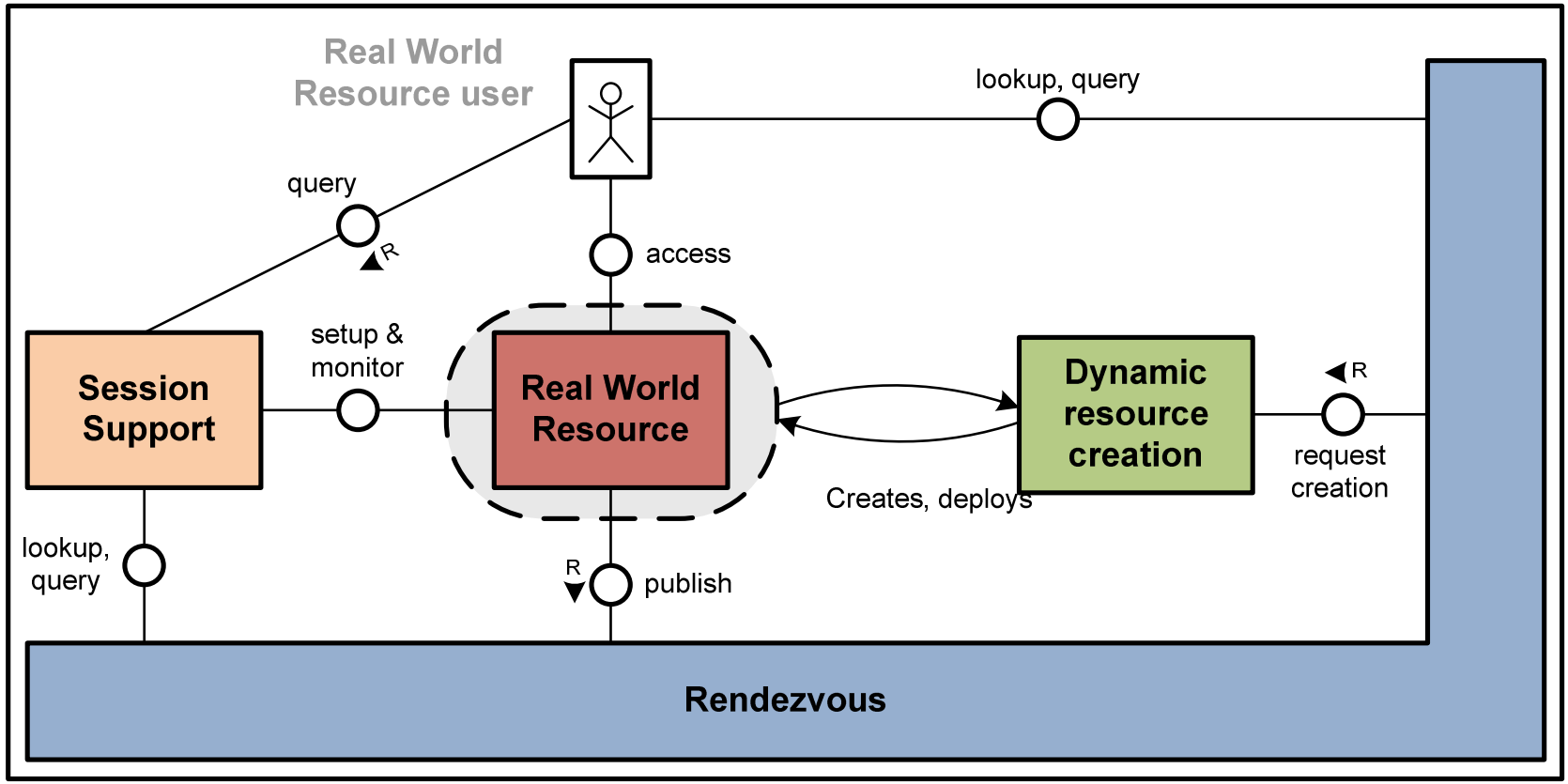
Context query: Entity/attribute example

Task: "*get* the *Temperature (attribute)* of *Room 45 (entity ID)*"

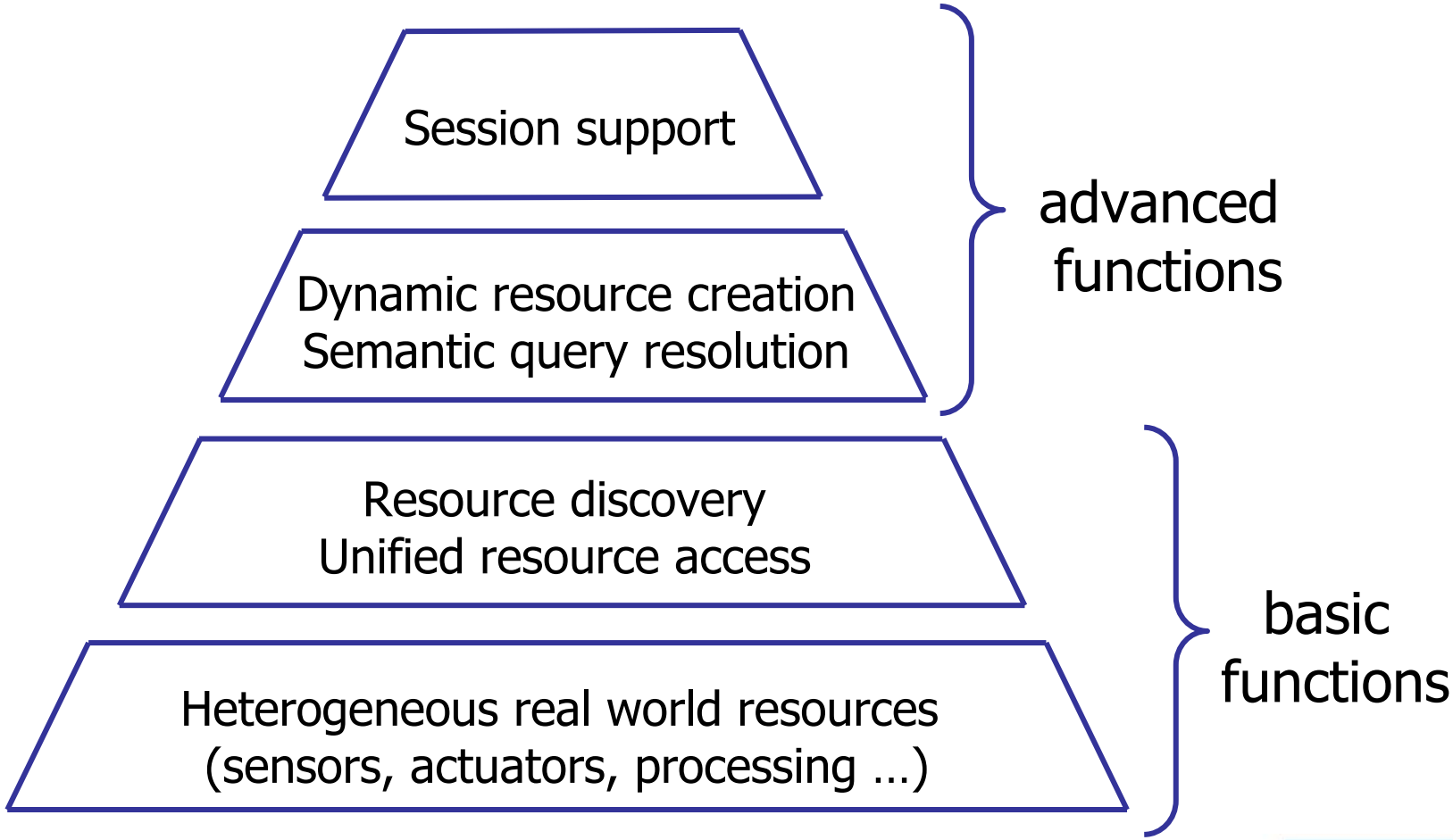


Entity	Attribute	Res ID	Operation ID	Input	Output	Pre-Condition	Post-Condition
Room45	**temp**	**tempSensor1**	**getTemp**	**-**	**Temp**	**-**	**-**
...	**...**	**...**	**...**	**..**	**...**	**-**	**-**

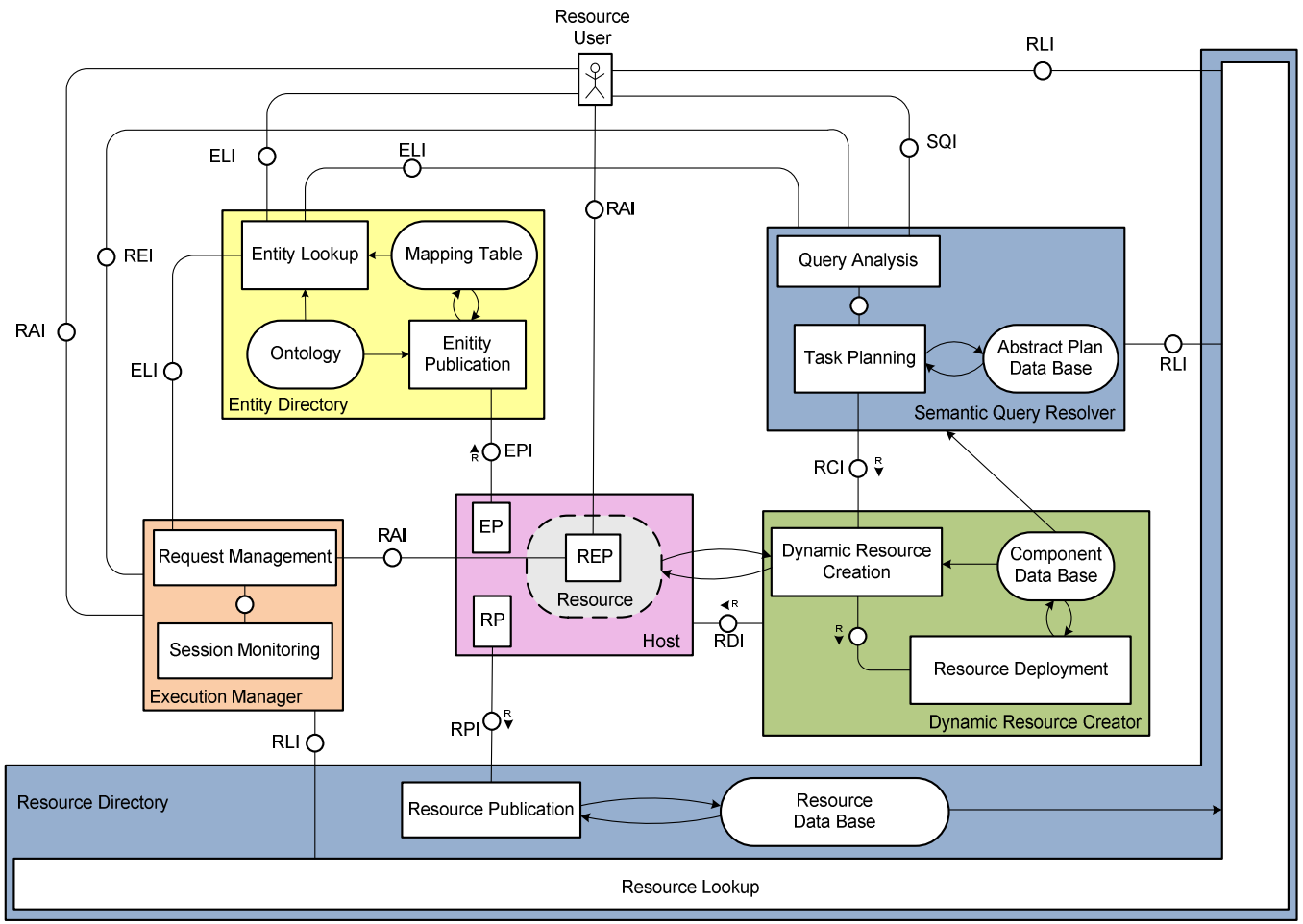
SENSEI components – logical view



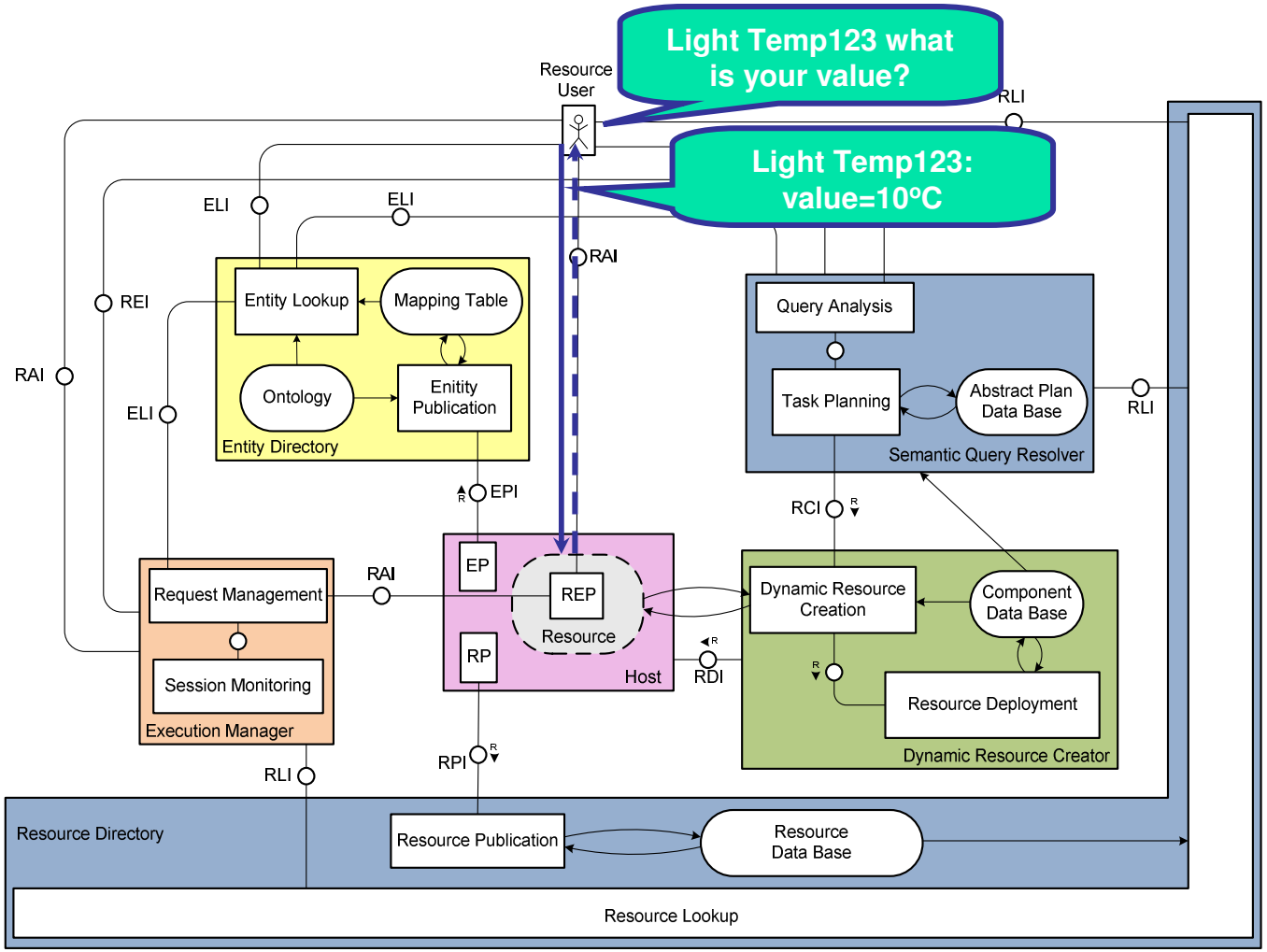
Functions and their interdependencies



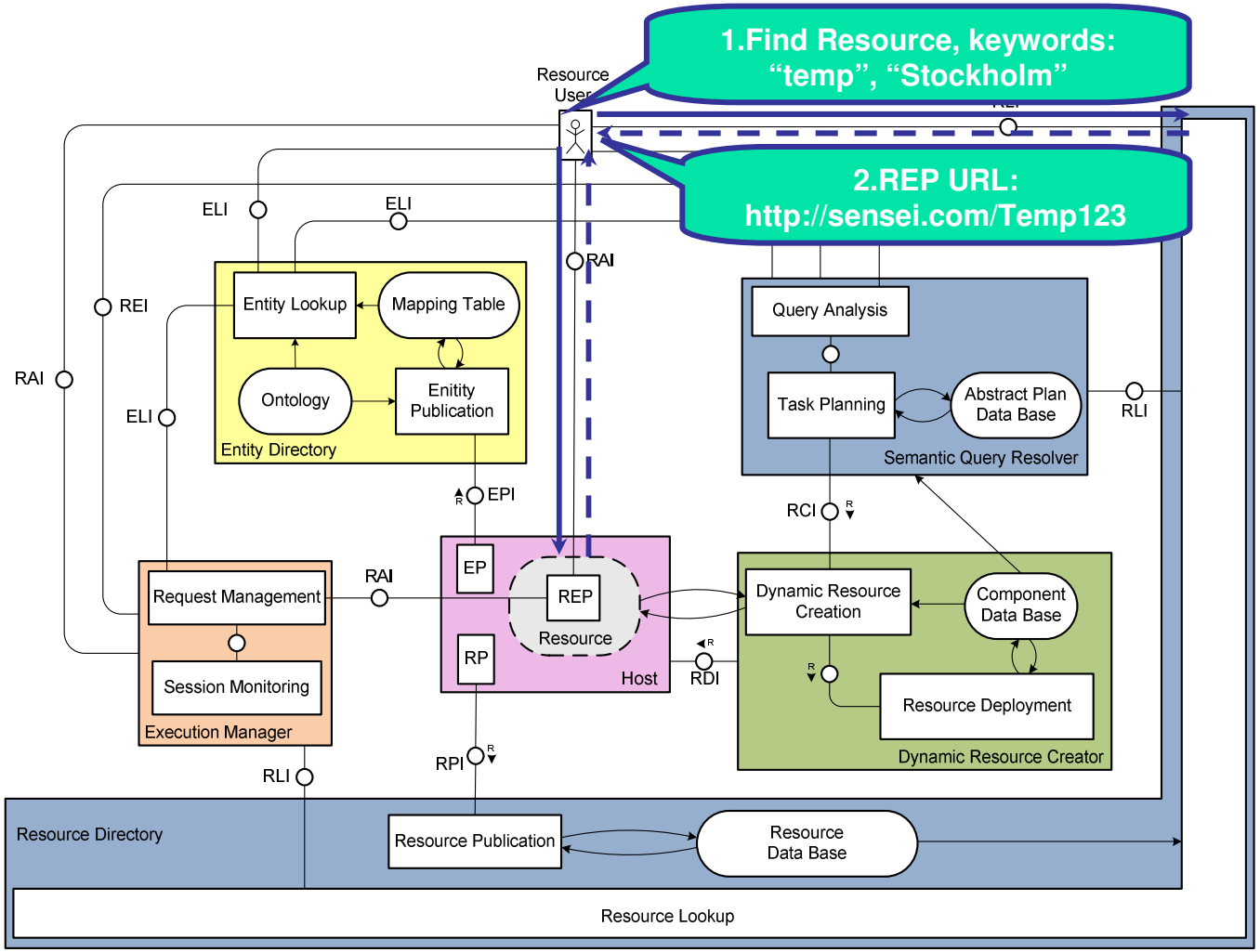
System components – network view



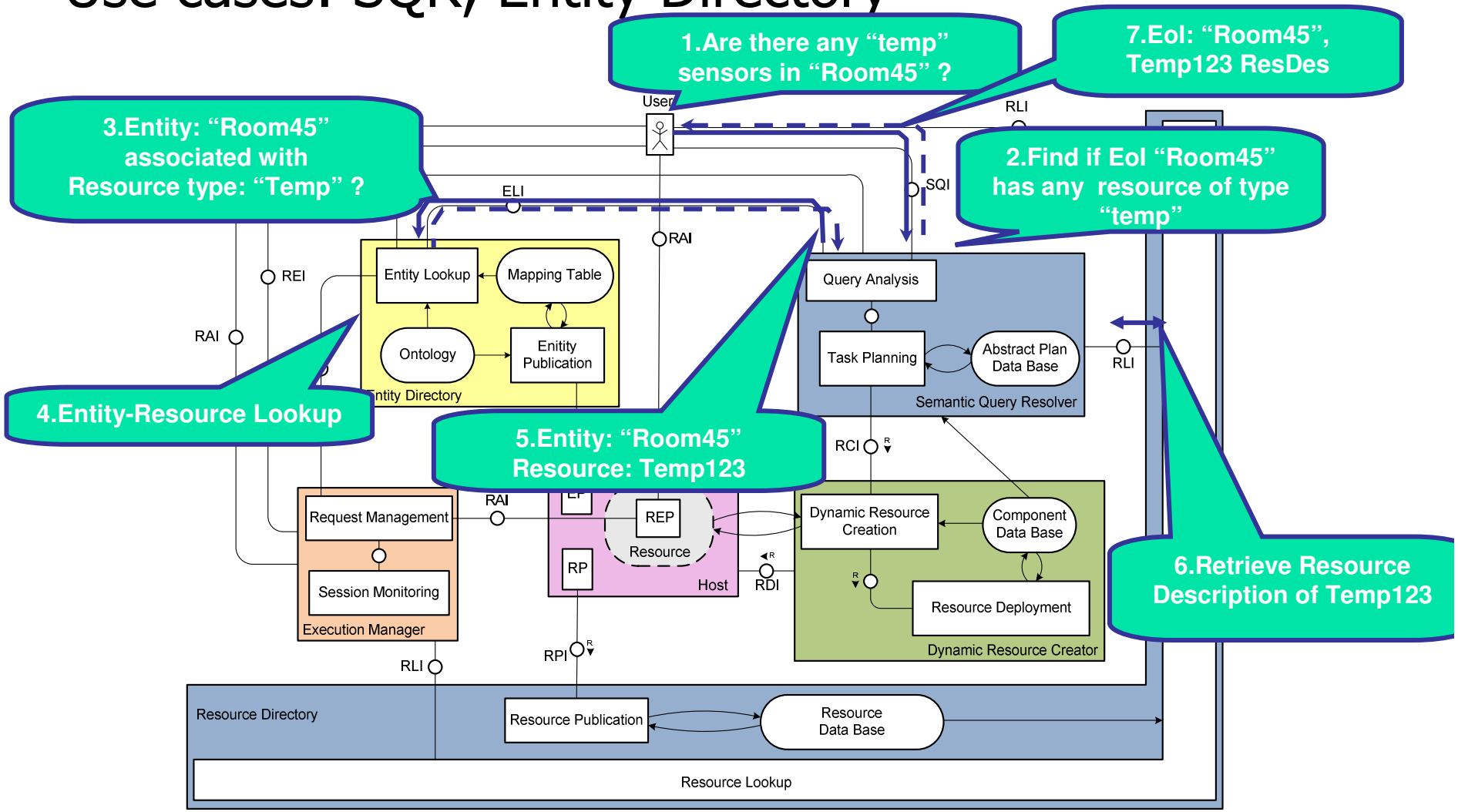
Use cases: Direct interaction with Resource



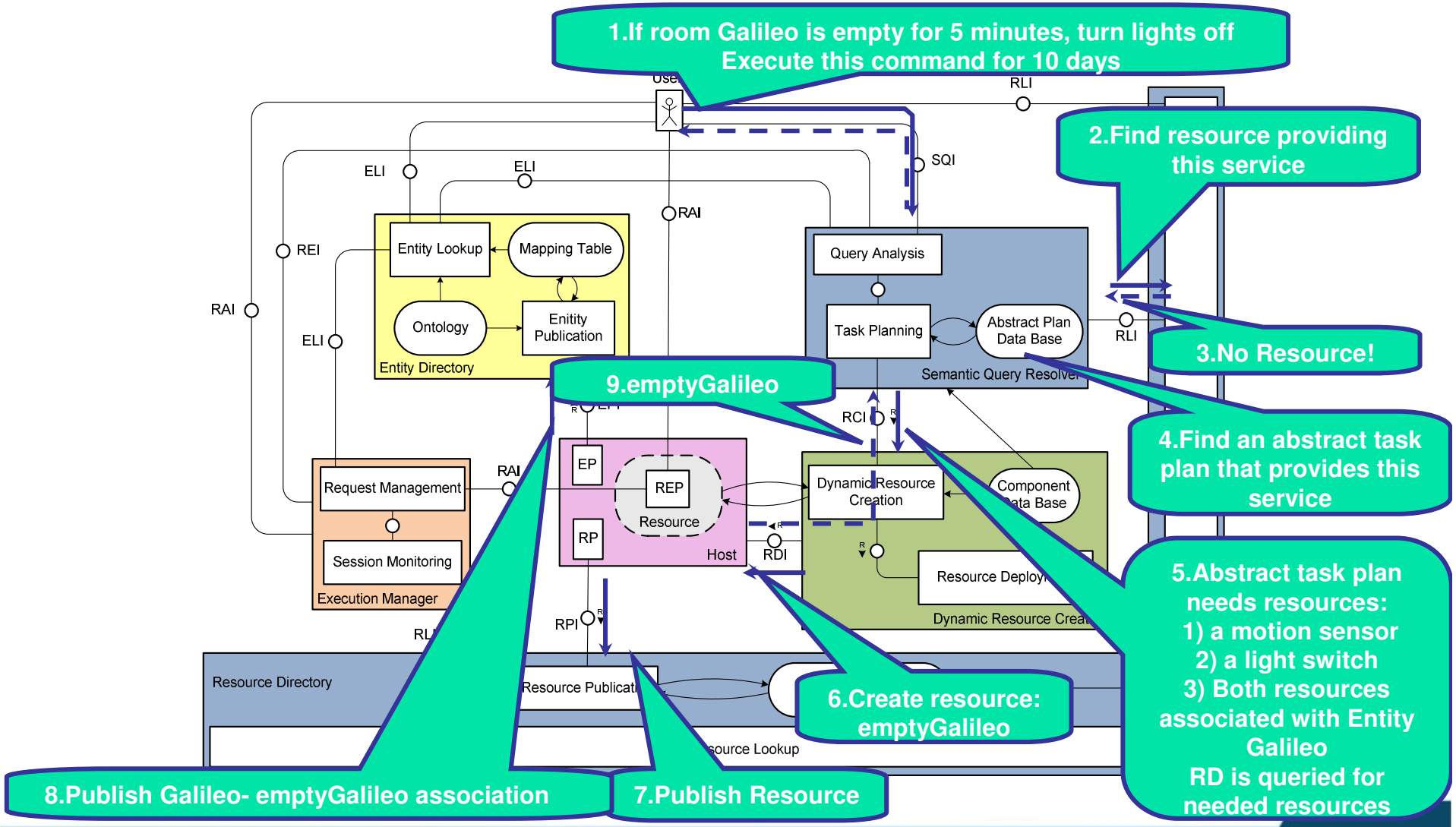
Use cases: Rendezvous, Resource Directory



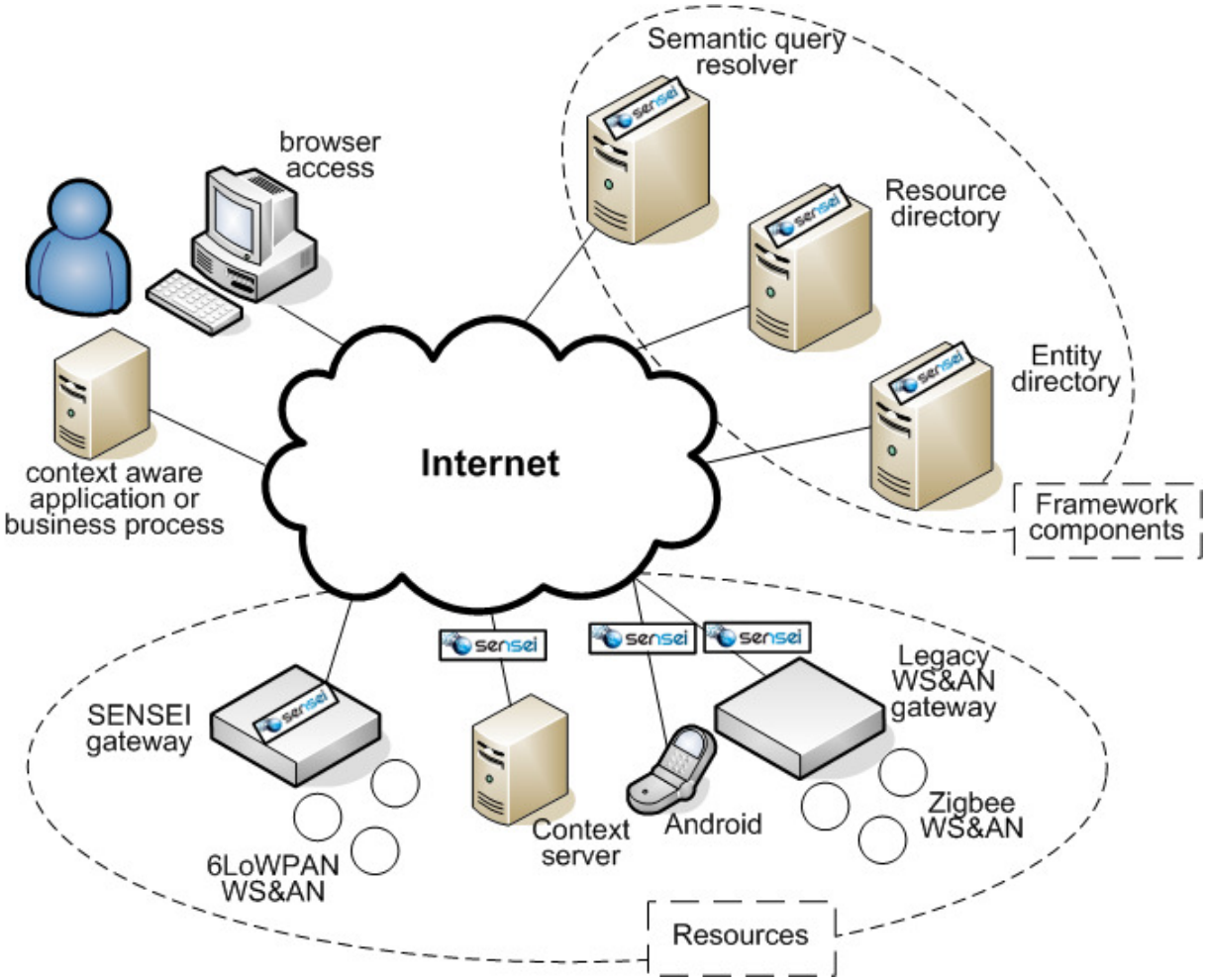
Use cases: SQR, Entity Directory



Use cases: Long term Actuation Loop



Deployment setup



Gateway

Mozilla Firefox Wed Jun 16, 14:08

File Edit View History Bookmarks Tools Help

http://localhost:8000/


```
-<rdf:RDF>
  <res:Gateway rdf:about="C++ Gateway" res:hasDomain="mobile.unipd.it" res:hasName="CFR-Netbook" res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/"/>
 -<rdf:Seq>
  -<res:Plugin rdf:about="Skeleton" res:hasResources="2">
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/test/1"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/test/2"/>
   </res:Plugin>
  -<res:Plugin rdf:about="Sensei" res:hasResources="24">
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/sensei"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/sensei/rd"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/sensei/stats"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/s/temp"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/s/light"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/s/irlight"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/s/humy"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/s/b1"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/p/battery"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/a/led0"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/a/led1"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0004/a/led2"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0005"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0005/s/temp"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0005/s/light"/>
     <res:Resource res:hasURL="http://sensei-tinyos.broker.freenet6.net:8000/0000-0000-fffe-0005/s/irlight"/>
```


Done

```xml
<Resources xsi:noNamespaceSchemaLocation="ResourceDescription.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSch
    <Resource-Description>
        <Resource-ID>urn:sensei:&domain;:Telosb:temp:&eui64;</Resource-ID>
        <Name>Temperature sensor</Name>
        <Tag>urn:sensei:wsan:&wsan;</Tag>
        <Tag>urn:sensei:node:&eui64;</Tag>
        <Tag>urn:sensei:resourcetype:regular</Tag>
        <RAI-Description>
            <RAI-ID>0</RAI-ID>
            <REP-Locator Expiration-Time="&expiration;">http://&ipaddress;/&nodeid;/s/temp</REP-Locator>
            <Document-Link>urn:sensei:rai:sensor</Document-Link>
        </RAI-Description>
        </Resource-Description>
    <Resource-Description>
        <Resource-ID>urn:sensei:&domain;:Telosb:light:&eui64;</Resource-ID>
        <Name>Light sensor</Name>
        <Tag>urn:sensei:wsan:&wsan;</Tag>
        <Tag>urn:sensei:node:&eui64;</Tag>
        <Tag>urn:sensei:resourcetype:regular</Tag>
        <RAI-Description>
            <RAI-ID>1</RAI-ID>
            <REP-Locator Expiration-Time="&expiration;">http://&ipaddress;/&nodeid;/s/light</REP-Locator>
            <Document-Link>urn:sensei:rai:sensor</Document-Link>
        </RAI-Description>
        </Resource-Description>
    <Resource-Description>
        <Resource-ID>urn:sensei:&domain;:Telosb:irlight:&eui64;</Resource-ID>
        <Name>Infrared Light sensor</Name>
        <Tag>urn:sensei:wsan:&wsan;</Tag>
        <Tag>urn:sensei:node:&eui64;</Tag>
        <Tag>urn:sensei:resourcetype:regular</Tag>
        <RAI-Description>
            <RAI-ID>2</RAI-ID>
            <REP-Locator Expiration-Time="&expiration;">http://&ipaddress;/&nodeid;/s/irlight</REP-Locator>
            <Document-Link>urn:sensei:rai:sensor</Document-Link>
        </RAI-Description>
        </Resource-Description>
    <Resource-Description>
        <Resource-ID>urn:sensei:&domain;:Telosb:humy:&eui64;</Resource-ID>
        <Name>Humidity sensor</Name>
        <Tag>urn:sensei:wsan:&wsan;</Tag>
        <Tag>urn:sensei:node:&eui64;</Tag>
        <Tag>urn:sensei:resourcetype:regular</Tag>
        <RAI-Description>
```

Different Issues

- Connectivity
- Mobility (we can use semantics!)
- Resource search and discovery (we use semantics)
- Data fusion (we use semantics)
- Interoperability ☺
- Efficiency
- Security, Privacy, Trust (no semantic model at the moment)

SENSEI - Target outcomes

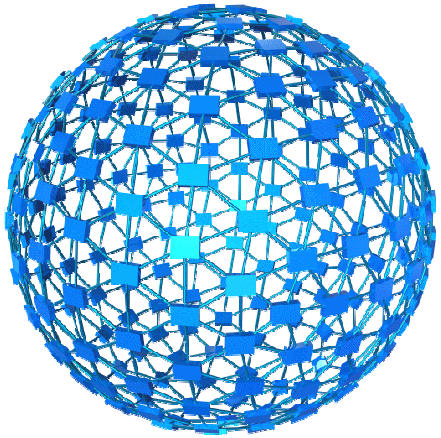
- A highly scalable architectural framework with corresponding protocol solutions that enable easy plug and play integration of a large number of globally distributed WS&AN into a global system – providing support for network and information management, security, privacy and trust and accounting.

- An open service interface and corresponding semantic specification to unify the access to context information and actuation services offered by the system for services and applications.

- Efficient WS&AN island solutions consisting of a set of cross-optimised and energy aware protocol stacks including an ultra low power multi-mode transceiver targeting 5nJ/bit.

- Pan European test platform, enabling large scale experimental evaluation of the SENSEI results and execution of field trials - providing a tool for long term evaluation of WS&AN integration into the Future Internet.

Semantic Sensor Networks



It's all about Collaboration and Communication

- The Real World Internet will enable forms of collaboration and communication between people and things and also between things themselves in the physical world.

- "*embedding intelligence in our environment and stimulating the creation of innovative products and new business opportunities*"*.

- "The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in co-operation." [Berners-Lee *et al*, 2001]

[* Panagiotis Tsarchopoulos, Digital Cities, February 2006]

Semantic Sensor Web

- The Semantic Sensor Web (SSW) is an approach to annotating sensor data with spatial, temporal, and thematic semantic metadata.

- This technique builds on current standardization efforts within the Open Geospatial Consortium (OGC), Sensor Web Enablement (SWE), and extends them with Semantic Web technologies to provide enhanced descriptions and access to sensor data.

Semantic Sensor Web

- The ideal situation is bringing the sensor data to the document level.
- Search, discovery, access mechanisms
- Energy efficiency, Security/Privacy, and QoS issues.

Where and How to use Semantics and Service technologies

- Observation and Measurement (O&M) (SENSEI ☺)
- Context modelling (SENSEI ☺)
  - Context and Entity of Internet models (SENSEI ☺)
- Middleware and Resource Access (SENSEI ☺)
  - Unified access (SENSEI ☺)
  - Service Oriented Architecture (SENSEI ☺)
- Resources and Resource Directory (SENSEI ☺)
  - Search and discovery (Semantic Query Resolver) (SENSEI ☺)
  - Domain knowledge (ontologies) (external domain knowledge and common ontologies) (Linked-data?)

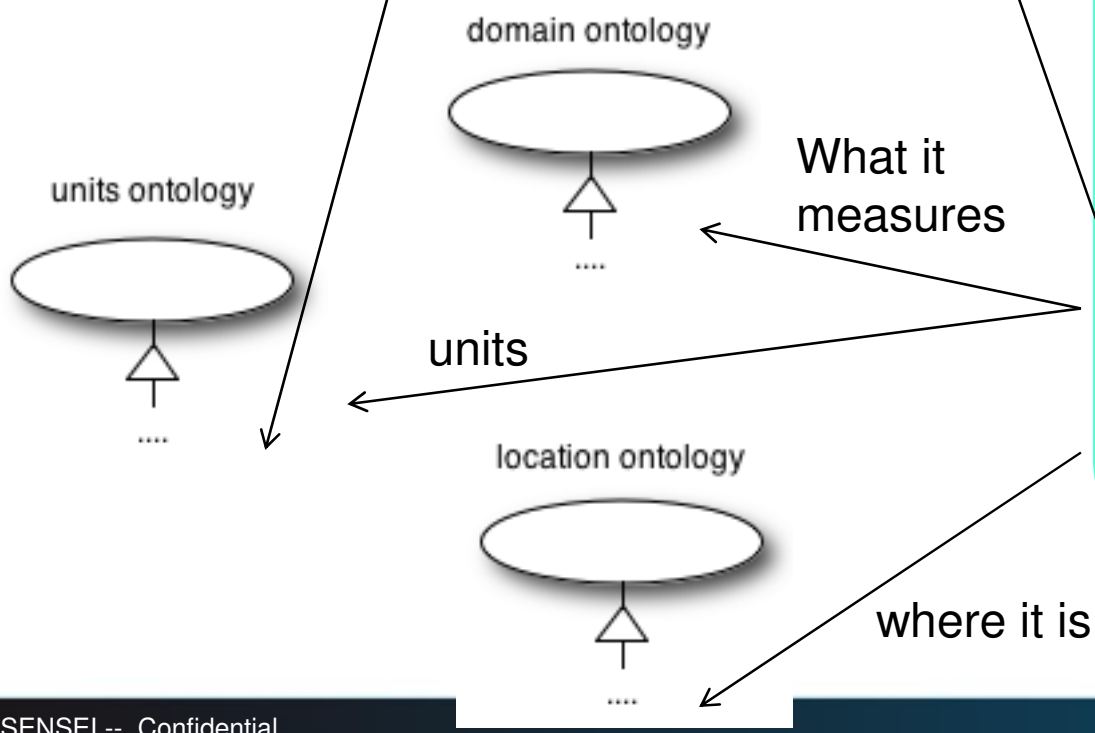
W3C Incubator Group, SSN-XG

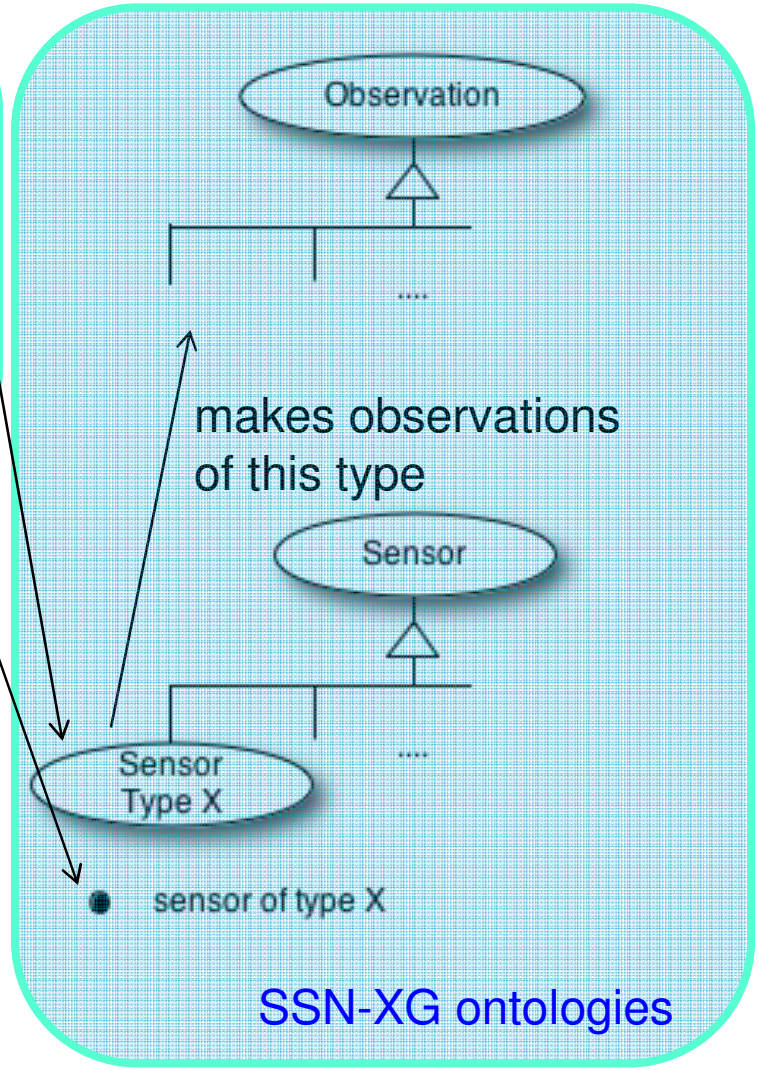
- W3C Incubator Group on Semantic Sensor Networks launched in March 4th, 2009.
  - The SSN-XG will work on two main objectives:
    - the development of ontologies for describing sensors, and
    - the extension of the Sensor Markup Language (SML), one of the four SWE languages, to support semantic annotations.
  - SSN-XG is begining of the process of defining these...

W3C SSN-XG Scope

SSN-XG annotations

```
<om:Observation>
    <om:samplintTime><gml:TimeInstant>...</gml:TimeIn
    <om:procedure xlink:role="http//www.w3.org/2009/I
                  xlink:href="http//www.w3.org/2009/I
    <om:observedProperty xlink:href="http//www.w3.org
    <featureOfInterest xlink:href="http://sws.geoname
    <om:result uom="http//www.w3.org/2009/Incubator/s
</om:Observation>
```



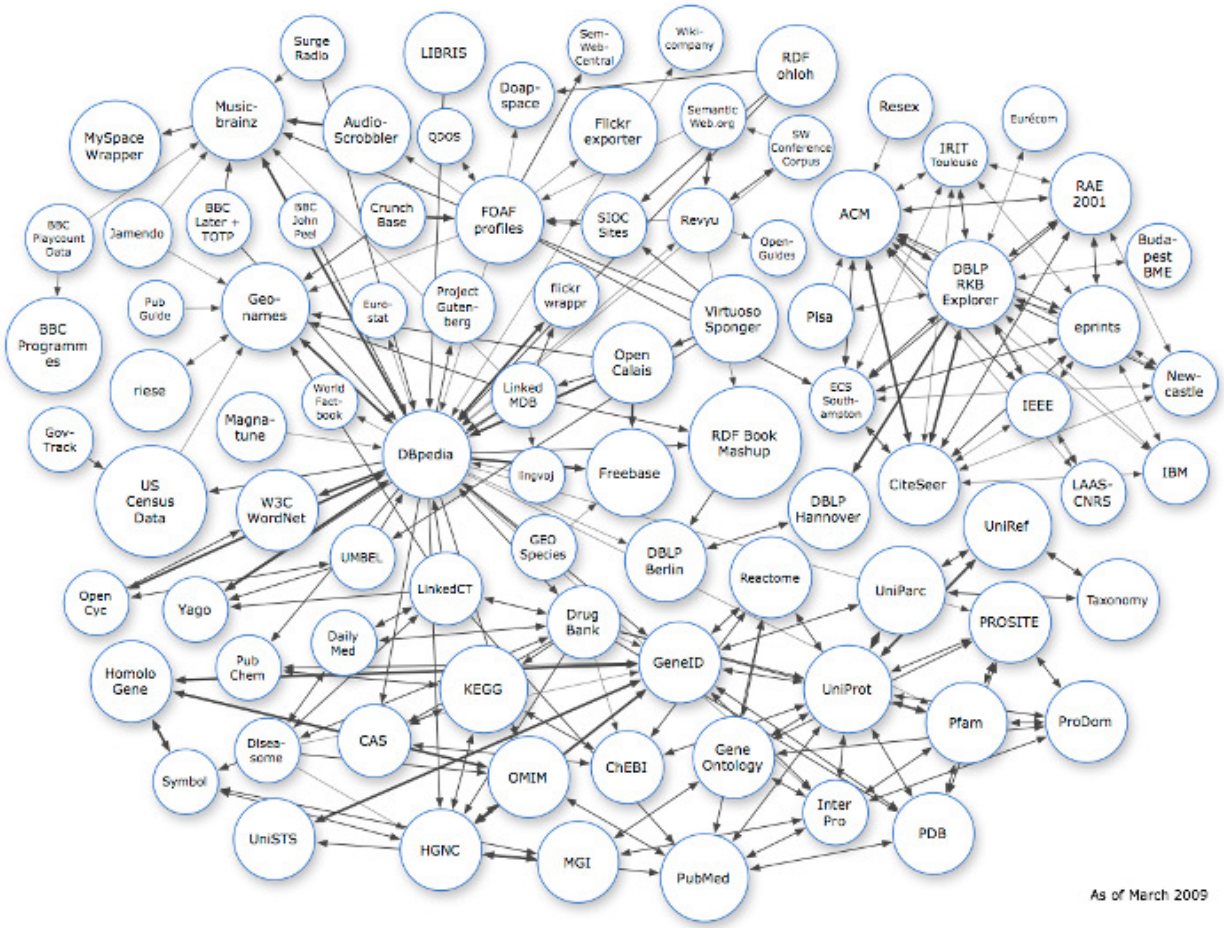


Semantic Integration

- Semantics allows you to create reusable knowledge that helps to
  - understand who is talking to who
  - who is doing what
  - and what the information means
- This enables the integration of information as knowledge.
- On a large scale this machine interpretable information is a key enabler and a necessity for the IoT.

[Presser, 2009]

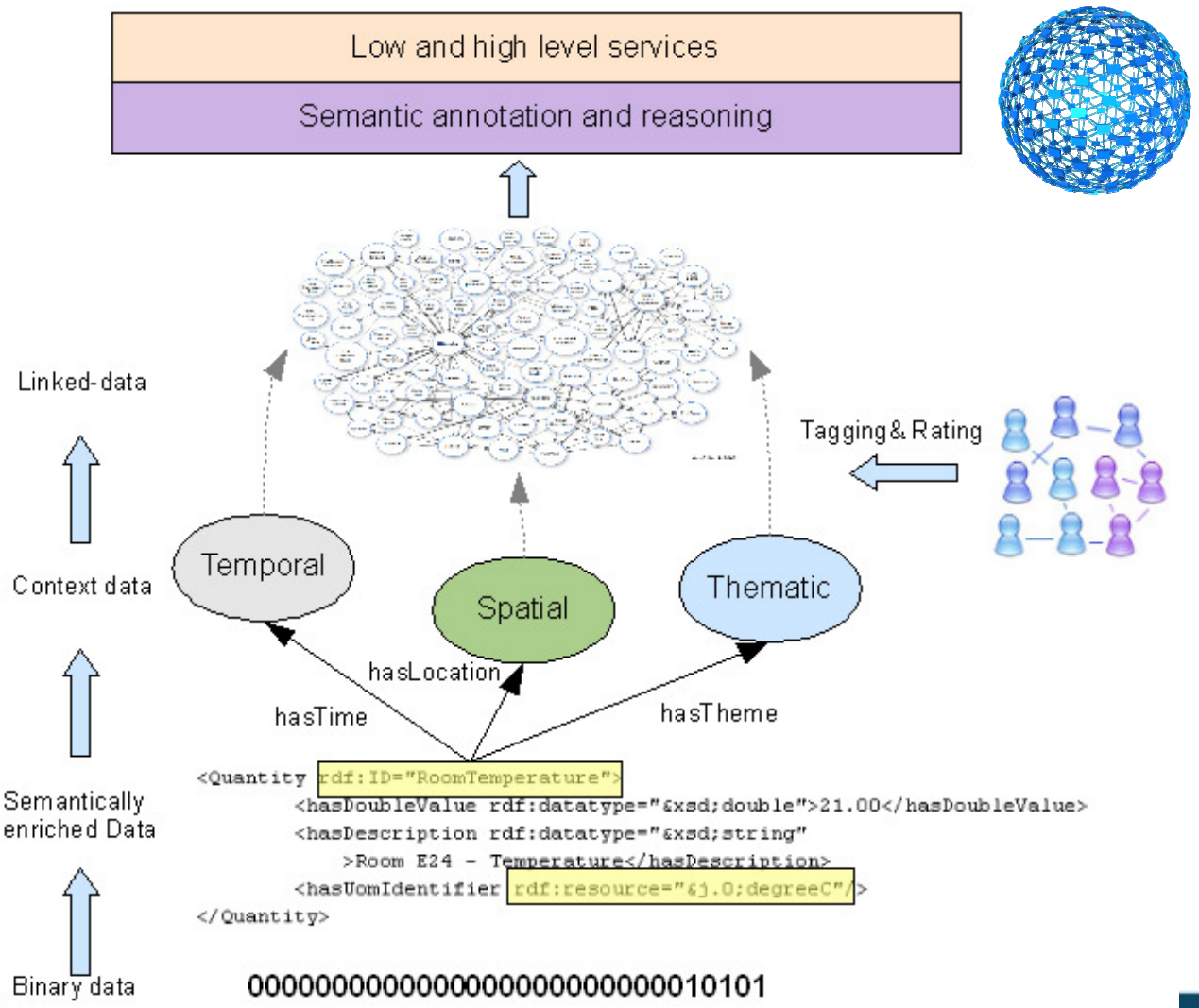
Linked Data- Connecting distributed data across the Web



Linked data principles

- The principles in designing the linked data are defined as:
  - using URI's as names for things;
  - using HTTP URI's to enable people to look up those names;
  - provide useful RDF information related to URI's that are looked up by machine or people;
  - including RDF statements that link to other URI's to enable discovery of other related things of the web of data;

Sensor data and Linked data



Key challenges – Semantics

- Where are we?
  - The core technological building blocks are now in place and (widely) available: ontology languages, flexible storage and querying facilities, reasoning engines, etc.
  - Standards and guidelines for best practice are being formulated and disseminated by e.g. the W3C.
  - For sensor data, there are some existing standards such as those provided by OGC and there also some ongoing work such as W3C's Semantic Sensor Web activity.
- What is still difficult?
  - Scale and time dependency of data
    - Storage and Querying of Masses of Dynamic Information

Key challenges – Semantics (cont'd)

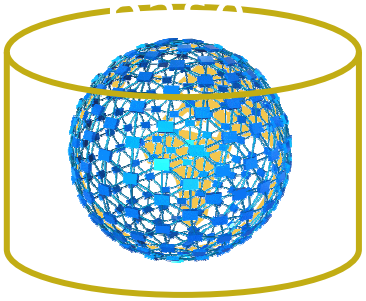
- What do we want to explain by semantics
  - Semantic modelling of sensors and sensor data
  - Augmentation of the domain knowledge?
- How to create useful descriptions without modelling the whole universe
  - Interoperability of domain specific semantics
  - Integration with Social Semantic Information Spaces
  - Linked data approach will be useful in this aspect
- Association of the semantically enriched data to (existing ontologies)
- Reasoning of the semantic data and user/service/agent interactions

Trends

- Tags/Sensors/Actuators are a global trend → information explosion
- IoT + Semantics + Linked-data → Integrated knowledge network
- Resources as web-level data and making them available in application level.
- Inspiring development of new services to enhance different business activities in enterprise applications.

The World at your Fingertips

The world is the knowledge



Despite Data Volume, Heterogeneity, Distribution, Dynamics:

Integration/access all that data like a set of interconnected resources in an information network!

1. **Structured Querying**
2. **Integrated Views**
3. **Aggregation, Analyses → Reasoning upon the data**

Conclusions

- SENSEI provides an architecture for integrating heterogeneous resources for real world information and interaction.
- Every deployed WSAN should plug into the RWI.
- Every WSAN research should look beyond its specific problem domain and keep the integration into RWI in mind.
- Achieving critical mass and global impact not only local solutions.
- Innovation has to now focus on providing a coherent framework and set of associated mechanisms to organically grow the RWI.

Links

- SENSEI Project:
  - http://www.ict-sensei.org/index.php
- SENSEI Scenarios
  - http://www.ict-sensei.org/Sensei_090422/
- Sensei Architecture Whitepaper
  - http://www.ict-sensei.org/index.php?option=com_docman&task=doc_download&gid=83&Itemid=49
- Future Internet Assembly: Real World Internet
  - http://rwi.future-internet.eu/

SENSEI Project

- Project Coordinator:
  - Laurent HERAULT, Head of Telecommunications Program, CEA-Leti, laurent.herault@cea.fr
- Technical Manager:
  - Alexander GLUHAK, CCSR, University of Surrey, a.gluhak@surrey.ac.uk
- Project Manager:
  - Francois BOURDEL, ALMA Consulting Group, fbourdel@almacg.com

Acknowledgments

- SENSEI project documents and deliverables.
- SENSEI WP2– Sensor Information Services presentation, April 2010.
- Mirko Presser, Trends and Promises The Internet of Things, CCSR, University of Surrey, May 2009.
- W3C Semantic Sensor Networks Incubator Group, An Ontology for Sensor Networks, W3C, 2010.

Acknowledgments

- Some of the content described in this presentation are presenter’s views and do not necessarily reflect SENSEI consortium's opinion.

- Thank you for your attention!