Sensor and Actuator Resource Architecture

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ABSTRACT
This paper briefly presents some of the aspects of the European 7th Framework Programme research project SENSEI architecture towards the Internet of Things.

1. INTRODUCTION
The research project SENSEI [1][2] provides an architecture for easy, open and standardized access to services based on sensors and actuators. The architecture abstracts the sensors, actuators and other functionality such as processing software as resources. The concept of the resource is central as it provides a horizontalization point for resource users (in general applications and non-human users) to access sensors, actuators and processing software.

SENSEI represents the physical world as two main levels of abstraction: the resource and the context level. On the resource level, resource users directly interact with resources. Sensor-based resources typically provide information either in the form of raw values or as observations or measurements, which include the raw value and additional meta-information regarding the type of provided information, e.g., location or temperature. SENSEI offers rendezvous support services to allow a resource user to locate suitable resources based on desirable properties while allowing resources to advertise these properties. Direct interaction between a user and a resource is suitable for context-unaware applications.

On the context level we assume that people, places and things constitute a set of Entities of Interest (EoI). The ultimate goal of the SENSEI architecture is the real world context information of these Entities of Interest. Examples include the activity of a person, health of a car or energy situation of a building. The entity context information is dynamically associated with sensor, actuator and processing resources that provide information or control capabilities relevant to the entity. For instance, a temperature sensor resource (e.g. `http://rephost.ericsson.com/s/temp`) is associated with the room (e.g. room 123) where it resides and one piece of the room context information (room temperature). The focus of this paper is the realization of the resource level of our architecture, and not the context level. The context level can be viewed as a generalized presence model.

SENSEI offers community management support services that allow open interactions as well as security enforced interactions that enable an information market place. Community management and security considerations are not covered here.

2. KEY CONCEPTS

2.1 The Resource as a first class citizen
Sensors, actuators and processing resources are abstracted as Resources in the SENSEI architecture. Apart from sensors and actuators, a processing resource is typically a software component that can further process sensor data or actuator commands, e.g. perform sensor data aggregation and trigger an actuator on the aggregation result. The concept of a Resource is similar to the Web Resource [4], i.e., a resource that has one globally unique identifier since it is part of the Internet, accessible by anyone typically through a REST interface and discoverable by anyone by means of associated metadata such as simple string tags or semantic information. Despite the changes in the details (e.g. resources offering other interfaces apart from REST), the ambition to provide an abstraction of sensors and actuators still holds. In contrast to the web resource the interfaces are not simple (REST CRUD, Create/Read/Update/Delete) but open-ended, in which case REST can be one option. The SENSEI resource still has a unique identifier and is described by metadata for easy reference and discovery.

2.2 Decoupling between the actual sensors/actuators and the resource access function
The heterogeneity of the sensor devices, gateways and in general sensor and actuator deployments motivated the choice to decouple the host of a sensor or actuator (e.g. a tiny battery powered sensor node in a home environment) and the host of the software (Resource Endpoint or REP) used by resource users to access the sensor data. This is also motivated by the heterogeneity of networking technologies of typical legacy sensors/actuators (Bluetooth, WiFi,, 6LoWPAN, ZigBee, Z-Wave, KNX, etc) and the fact that most of these technologies don't have a clear networking interoperability with wide area networking technologies. Nevertheless even if there is a clear way to bridge the two domains (short-range radio network and wide area network), the sensor/actuator node: a) is susceptible to denial of service attacks, b) uses different security protocols and c) is not always available. All these are due to the low computational and communication and energy capabilities of sensor nodes. Of course optimizations can occur in more capable nodes.

2.3 Resource Directory
In the near future, when the number of sensor and actuator resources will outnumber the current number of users, providing means to discover or lookup resources will be a necessity. To satisfy such a requirement functionality SENSEI has specified a Resource Directory (RD), where heterogeneous resources can register and be discovered by machines or humans searching through the registered resource

descriptions when searching for a particular service (e.g. an HTTP on `http://rd.sensei.org/rli?tag=light&tag=Vuokatti`, searches for resources with description tags `"Vuokatti"`, `"light"`, Figure 4 shows a matching resource description). Resource Directories can be distributed across domains and peered.

3. IMPLEMENTATION AND DEPLOYMENT

SENSEI had as one of its goals to build a Pan European Testbed[3] to provide a proof of the SENSEI concepts. One high level view of the testbed is shown in Figure 1. The resources offered by this testbed are sensors, actuators and processing resources (residing or processing servers). The resources are also hosted on hosts with distinct capabilities. There are resources that are hosted on tiny sensor nodes in Wireless Sensor and Actuator Networks (WS&AN), running 6LoWPAN and ZigBee, and the resource user access them through mediating software components residing on gateways. There are also resources offered by capable resource hosts such as mobile phones or servers (e.g. processing resource server in Figure 1). All the above resources can be directly accessed by resource users and they constitute along with the Resource Directory the resource level of abstraction as mentioned above. The rest of the support services (Entity Directory, Semantic Query Resolver) enable the context level abstraction not described here. SENSEI defines for the purposes of the testbed a set of Well-Known Resource Types (WKRT, see examples below). Each of the well-known resources has specific REST interfaces described in WADL files. The sensor nodes in a WS&AN use an early version of CoAP[5].

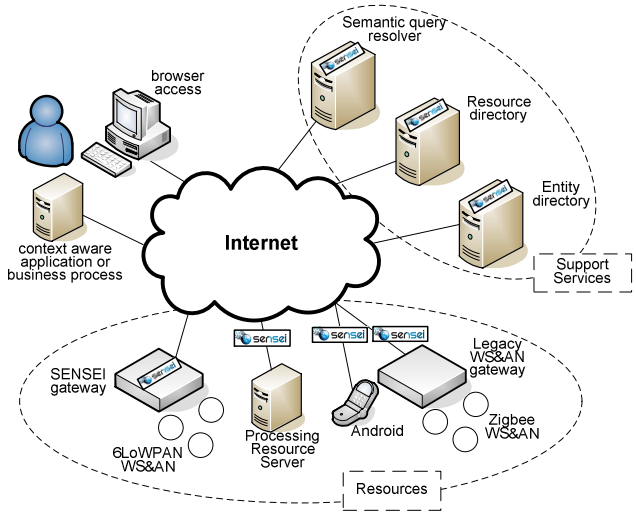

Figure 1. SENSEI testbed

4. EXAMPLES

A resource is described with a resource description that is stored on the Resource Directory upon registration. The description (Figure 4) has among other information the following main parts:

- (One) Resource identifier: This is a URN with a specific format shown in Figure 2.
- Resource Access Interface (RAI) descriptions. A resource may have multiple RAIs. Each RAI has:
  - RAI identifier: an integer
  - Document link: URI to a document describing the interface, e.g. for REST interfaces this is a link to a WADL file. For the well-known resource types, the URI can be a simple URN from the following set:
    - `urn:sensei:rai:sensor:` a sensor resource which has a REST interface to read the sensor data
    - `urn:sensei:rai:parameter:` a software resource which has a REST interface to monitor and configure management parameters
    - `urn:sensei:rai:actuator:` a actuator resource which has a REST interface to send actuator commands
    - `urn:sensei:rai:code:` a software resource which has a REST interface to upload new code on a sensor node, mainly used for management
  - Resource Endpoint (REP) Locator: A RAI may have multiple REPs. Format and examples are shown in Figure 3.
- List of tags: tags can be simple string tags (simple resource description) identifying the resource, e.g. `"Stockholm"`, `"temperature"` or entire RDF documents with semantic description of the resource (for advanced resource description), location, observation area and resource interfaces.

`urn:sensei:` [domain] `:` [device type] `:` [resource name] `:` [unique identifier or name], where:

[domain] – The domain of the resource owner; the domain name is not related to the Internet Domain name space, i.e. it does not imply anything on the point of attachment but only indicates ownership

[device type] – Used to describe the device or entity providing this resource. For example the manufacturer and type of a physical device, or the kind of software providing a virtual resource.

[resource name] – As a physical device may have many resources, this field differentiates between those. Might be e.g. the type or model number of a sensor.

[unique identifier or name] – A unique number or name differentiating devices with the same [device type]. This may be e.g. the EUI-64 of an IEEE 802.15.4 device, the UUID of a device, the HIT of a device or e.g. a serial number.

Example:

`urn:sensei:ericsson.com:sensor:temp:56f9-0783-0013-ad53`

Figure 2. Resource identifier format and example

[protocol] `://` [REP host identifier] [resource path]

[**protocol**]: protocol identifier, e.g. `http`

[**REP host identifier**]: communication endpoint address (FQDN, IP address, HIT identifier etc): host address on which REPs are hosted, e.g. `gateway.sensinode.com, 192.127.0.0.1`

[**resource path**]: path to the resource offered by the REP, e.g. `node1/s/light, s/temp`

Examples:

`http://gateway.sensinode.com/node1/s/light`

`http://192.127.0.1/s/temp`

Figure 3. REP Locator format and examples

```
<?xml version="1.0"?>
<Resources xsi:noNamespaceSchemaLocation="ResourceDescription.xsd"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
   <Resource-Description>
      <Resource-ID>urn:sensei:sensei.org:Telosb:light: fa80-0342-001a-4201</Resource-ID>
      <Name>Light sensor</Name>
      <Tag>urn:sensei:wsan:Vuokatti</Tag>
      <Tag>light sensor</Tag>
      <Tag>urn:sensei:node:fa80-0342-001a-4201</Tag>
      <RAI-Description>
         <RAI-ID>0</RAI-ID>
          <REP-Locator>http://gateway.sensinode.com/node1/s/light</REP-Locator>
          <Document-Link>urn:sensei:rai:sensor</Document-Link>
      </RAI-Description>
   </Resource-Description>
</Resources>
```

Figure 4. A simple resource description as registered by a resource to the Resource directory

5. ACKNOWLEDGMENTS

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6. REFERENCES

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