Publishing LO(D)D:
Linked Open (Dynamic) Data for Smart sensing and Measuring environments

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Goals

- Enable sensor networks to publish their data in a standard way
- Enable distributed applications to consume sensor data from different sources
- Enable data publication, consumption, computation, re-publication, etc with minimal effort
- Extend the Linked Open Data cloud with time-varying (sensor) data streams
Outline

- Context and Motivation
- Proposed Architecture
- Proposed solutions
- Experimental results
- Conclusions
Context

Smart Sensing and Measuring Environments
- Smart Homes
- Sensor and Actuator Networks
- Smart Factories
- Smart Grid
- Environment monitoring
- Social mobile applications

Smart Appliances

Affordable and efficient sensors
Smart Sensing and Measuring Environments

Smart Appliances

energy (active, reactive, reverse, kVAR, ...)

acceleration

compass

air pressure

temperature

light

acceleration

compass

GPS

proximity

microphone

camera

BT Scan

Affordable and efficient sensors
Context

Smart Sensing and Measuring Environments

Smart Appliances

Affordable and efficient sensors

- Motion
- Smoke
- Gyroscope
- RFID
- Pressure
- 2D codes

Meaningful content related to affordable and efficient sensors for smart appliances.
Motivation

Applications need to access information from multiple environments

Standard way to publish and consume information

- About accessible environments
- About available appliances, sensors and their characteristics
- About the actual data measured by sensors
Approach

Applications need to access information from multiple environments

**Standard** way to publish and consume information

- About accessible environments
- About available applications, sensors and their characteristics
- About the actual data measured by sensors

Adopt Semantic Web «**Linked Open Data (LOD)**» approach

**Static information:**
Can be encoded in RDF according to a public Ontology

**Dynamic information:**
New approach to represent streams of RDF events
General LO(D)D Architecture

Smart Environment

Producer Application publishes

Static information about sensor streams

monitors

E

G

F

P
General LO(D)D Architecture

- **Smart Environment**
- **Producer Application**
- **Static information about sensor streams**
- **Sensor data channel**
- **Sensor data channel**
- **Sensor data channel**

 Producer Application publishes updates to the Smart Environment, which monitors and describes the sensor data channels.
General LO(D)D Architecture

Producer Application publishes Static information about sensor streams

Smart Environment

E G E

G

G

Producer Application

subscribes

Consumer Application

receives

Sensor data channel

E G E

G

G

G

E G E

E G E

G

G

G

G

Sensor data channel

Sensor data channel

Sensor data channel

updates

monitors

describes

E G E

E G E

E G E
Proposed solutions

- Open source libraries and API to enable application to interact with LO(D)D data
- RDF document with meta-data (PID)
  - Publisher information
  - List of channels, their source data, their datatypes, and subscription URI/key
- RDF «fragments» representing each event
  - Contains: event#, sensor id, timestamp, value, unit of measure
- Uses publish-subscribe pattern as transport mechanism for distributing RDF fragments
Publisher Information Document (PID)

- According to lightweight «Publisher» ontology
- Contains declarations of all channels handled by this publisher – all needed static information
- Gives information to subscribe to channels
- Created by publisher API
- Published over http

```
<RDF:Description RDF:about="&Publisher;energymtr">
  <publisher:Location RDF:datatype="&xsd;string">
    Torino, Italia</publisher:Location>

  <publisher:subscribekey>sub-xxxxxx-42904d46dEEE</publisher:subscribekey>

  <publisher:channelName>Energy Meters</publisher:channelName>

  <RDF:type RDF:resource="&Publisher;Channel"/>
</RDF:Description>
```
Event data fragments

- Individual data points encoded in RDF
- Self-consistent information (e.g. Unit of measure)
- Standard syntax and semantics
- Application-independent representation
- Compact encodings available

```xml
<rdf:Description RDF:about = "&publisher;emergymtrChan1">
  <publisher:MeterNumber RDF:datatype="&xsd;int">
    231
  </publisher:MeterNumber>

  <publisher:Unit RDF:datatype="&xsd;string">
    http://purl.oclc.org/NET/muo/ucum/unit/power-level/bel-kilowatt
  </publisher:Unit>

  <publisher:hasTimeStamp RDF:datatype="&xsd;dateTime">
    2012-02-02T13:06:41.056Z
  </publisher:hasTimeStamp>

  <publisher:hasCurrentValue RDF:datatype="&xsd;double">
    0.3
  </publisher:hasCurrentValue>
</RDF:Description>
```
Cloud based Transport mechanism

- Provides the updates to subscribers whenever publishers update data
  - New RDF fragments are sent to the cloud service
- Maintains list of subscribers
- Handles logic to provide transport from Publisher to many Subscriber in real time
- It makes the Publisher a “light-weight component”
  - Publisher is independent from the number of connected subscribers

PubNub

...and others
Publisher and Consumer APIs

- **Publisher Library**
  - Creates PID file and offers it on http
  - Creates channels onto cloud service
  - Sends updates to channel, encoding it in RDF

- **Consumer Library**
  - Parses PID file and provides channel information
  - Subscribes to one or more channels
  - Notifies application when new data is available, decoding it from RDF

- Same application may be producer and consumer at the same time
- Applications need not manage RDF explicitly
Preliminary Experiment

Building Infrastructure
Politecnico di Torino

poliEnergy PID

Publishes

P

Cloud

• 126 Electrical Meters.
• Take reading every 15 minutes
Preliminary Experiment

Building Infrastructure
Politecnico di Torino

- Publishes

Cloud

• 126 Electrical Meters.
• Take reading every 15 minutes

• Aggregates reading into 3 ranges.
• Publishes using 3 channels
Preliminary Experiment

Building Infrastructure
Politecnico di Torino

• 126 Electrical Meters.
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Cloud

• Aggregates reading into 3 ranges.
• Publishes using 3 channels
Conclusions

- Open applications with open data
- Exploiting existing standards (RDF and pub/sub)
- Extensible to different type of sensor data
- Highly scalable

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We provide this layer: Concrete

User defines this layer

Actual Provider Info: User Level