Sense2Web: A Linked Data Platform for Semantic Sensor Networks

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The current advancements in sensor networks and being able to manufacture low cost and energy efficient hardware for sensors has lead to a potential interest in integrating physical world data into the Web. The sensor networks range from tiny wireless artefacts to mobile devices (with many sensors) to large scale systems (in smart cities and environmental monitoring networks). Applications and users are typically interested in querying various events and requesting measurement and observation data from the physical world. Integration of data from physical objects, using embedded processors and sensors, into the Web is giving rise to the emergence of a new generation of systems. The incorporation of physical object data with the Web data, using information processing and knowledge engineering methods, enables the construction of "intelligent and interconnected things" and "smart environments". The current research mostly focuses on the communication and networking aspects between such devices. There is, however, relatively less effort concentrated on creating dynamic infrastructures to support integration of the data into the Web and provide unified access to such data on service and application levels. Utilising semantic Web technologies in the sensor networks results in a new concept, sometimes referred to as Semantic Sensor Networks. This paper describes a platform to publish Semantic Sensor Network data and to link the data to existing resources on the Web. The linked Semantic Sensor Web data platform, called Sense2Web, supports the publication of extensible and interoperable resource (i.e. sensor network and service resources) descriptions and observation and measurement data in the form of linked data. Sense2Web also supports the association of different sensor data to resources described on the Web of Data. In this paper we focus on publishing linked data to describe sensor data and sensor network resources descriptions and link them to other existing resources on the Web.

Keywords: Linked data, Ontology, Sensor, Semantic Sensor Web, Sensor Networks, Sense2Web

1. Introduction

The information collected from the physical world, in combination with the existing resources and services on the Web, facilitates enhanced methods of obtaining business intelligence, enabling the construction of new types of front-end applications and services, and could revolutionise the way organisations and people use Internet services and applications in their daily activities. There are currently a number of projects focused on developing large-scale sensor networks integrated into the Internet such as SENSEI, IOT-A, SensorWeb, and also there are existing work on creating service layers and network structures for sensor and actuator networks such as [1], [2], [3], the Open Geospatial Consortium (OGC) and the Sensor Web Enablement (SWE) activities [4]. These works are some of the ongoing efforts to develop underlying services for constructing global sensor networks.

1http://www.ict-sensei.org
2http://www.iot-a.eu/
4http://www.opengeospatial.org
There are currently standards and common frameworks to describe sensor data such as those provided in SWE’s specifications and W3C’s Sensor Ontology\(^5\). However, data interoperability in application domains and data relations to spatial (e.g. geographical location, relative relation in relation to other resources), temporal (e.g. availability, time zone) and thematic (e.g. unit of measurement, type of data, domain) attributes are not often considered in these specifications. Trust, privacy, security and reliability issues and also resource discovery are also issues that need to be considered in designing access and query mechanisms in large scale sensor networks. To automate data and service provisioning in sensor networks there is a need for a complete set of solutions, from requirement specification to discovery, reasoning and integration mechanisms. This paper describes the use of interoperable semantic data for this purpose. We discuss publishing data descriptions for the Semantic Sensor Networks in the form of linked data. This also includes the description of a gateway component that acts as an intermediary for capturing, delivering and presenting dynamic real world data to consumer applications and users. Collaboration, scalability and semantic interoperability are the key features in designing large-scale sensor networks to support efficient resource distribution and data communication. This generates networking resources which collect data from the physical world as well as data and services on the Web. Interlinking data from the physical world and the Web supports the provision of networked knowledge\(^5\). Annotation, processing and reasoning sensor data on a large-scale will be a challenging task for applications that publish and/or utilise this data from various sources. However, to some extent this is similar to challenges that the semantic Web community faces in dealing with the huge volume of ontologies and semantically annotated data from different sources and applications.

Linked data is one way to publish, share and connect data via URIs on the Web\(^6\). It focuses on interconnecting data and resources on the Web by defining relations between ontologies, schemas and/or directly linking the published data to other existing resources on the Web. The process can be done manually or (semi-) automatic mechanisms can be used to create the links. Publishing data as linked-data enables other related data and relevant information to be discovered and facilitates interconnection and integration of data from different communities and sources. In this paper we describe our Sense2Web platform.

Sense2Web facilitates the publication of linked sensor data and makes this data available to other Web applications via SPARQL endpoints\(^7\). Our main focus in this paper is sensor description data. The sensor observation and measurement data is also represented according to the model that we have developed in [6]. However, storing and querying observation and measurement data has other requirements, such as time-dependency, scalability, freshness and latency that are beyond the scope of this paper. We have also implemented a mash-up application using data from Sense2Web to demonstrate reasoning and interpretation of linked sensor data and sensor network resource descriptions.

The remainder of this paper is organised as follows: Section 2 describes semantic sensor networks. Section 3 discusses linked data principles and describes Linked Open Data concepts. Section 4 explains linked sensor data and linking sensor descriptions to existing resources on the Web. Section 5 demonstrates the Sense2Web platform for publishing and accessing linked sensor data and demonstrates a mash-up application using constructed linked data. Section 6 concludes the paper and discusses future work.

2. Semantic Sensor Networks (SSN)

Providing interoperable and machine-interpretable descriptions of sensor, observation and measurement data and interconnecting the data to other existing resources on the Web are fundamental steps in the construction of semantic sensor networks. Sheth et al. [7] propose annotating sensor data with spatial, temporal, and thematic semantic metadata and refer to this as the Semantic Sensor Web (SSW). This approach uses the current OGC and SWE specifications, extends them with semantic Web technologies and provides enhanced machine-interpretable semantic descriptions. The enhanced descriptions facilitate more autonomous access to sensor data and the spatial and temporal attributes enable enhanced discovery and utilisation of

\(^5\)http://www.w3.org/2005/Incubator/ssn/wiki/Incubator_Report
\(^6\)http://linkeddata.org/
\(^7\)http://semanticweb.org/wiki/SPARQL_endpoint
Associating sensor and sensor network data with other concepts (on the Web) and reasoning the data makes this information widely available for different applications, front-end services and data consumers. Semantics allow machines to interpret links and relations between the different attributes of a sensor description and also other data existing on the Web or provided by other applications and resources. Utilising and reasoning this information enables the integration of the data on a wider scale, known as networked knowledge [8]. This machine-interpretable information (i.e. semantics) is a key enabler for the semantic sensor networks.

We have developed a framework for publishing sensor data descriptions and for linking this data to other resources on the Web. The semantically enriched data is made accessible at HTTP level and thus is available for business processes and data integration and collaboration services. Another important aspect is the interoperability of the data and scalability of the framework. Utilising metadata and semantic annotations to describe sensor data and physical world resources in general enables different communities to exploit emerging data and exchange information and knowledge in a collaborative environment. User annotated resources and services similar to those employed by social Web and semantic Web, as well as common machine-interpretable descriptions and query interfaces, are key aspects in designing the framework.

Figure 1 shows an example of the integration of data from different sources. The example illustrates a parcel that is tagged with an RFID tag which is scanned every time it is loaded or unloaded. The post delivery van has a GPS sensor which reports its location and a twitter service is deployed to report the status of the parcel to interested twitter followers. In a semantic integration scenario each of these sensors and services need to be able to describe and/or discover what type of information is published and who can use this information. This includes the sensor or service descriptions and also the data reported from sensors and services. In this paper we provide gateway components and services to make the sensor data accessible to higher level applications and/or services and describe how the data is published as linked data in the Sense2Web platform. We also discuss how a consumer service/application can query and access this data using standard query mechanisms. The following describes a gateway component that enables Sense2Web to access sensor data and connects capillary sensor networks to higher level IP-based networks. The gateway component represents sensor data and the sensor descriptions via Web services that can be discovered and utilised in higher level services and applications.

2.1. Gateway design for Semantic Sensor Networks

We describe a gateway component for semantic sensor networks which connects the capillary sensor networks to higher application layers. In our design the sensor nodes are connected to the nearest gateway which runs on a more powerful machine. The gateway manages the connected sensor nodes provides access to sensor data through a service layer. The gateway runs on capable devices (often with persistent power supply) and supports several connection types such as the IEEE 802.15.4 compatible communications. The gateway component provides mechanisms for sensor nodes to handshake with available gateway components and to register their specification and capabilities in the form of node context information. The node context includes information such as time zone, avail-
ability, location, measurement capabilities and range.

Fig. 2. Gateway component for Semantic Sensor Networks

The gateway component is divided into three main layers. The layers and main interactions are shown in Figure 2. The connectivity layer establishes the connection with a capillary sensor network. A connector modules for each supported sensor/protocol platform should be developed. External nodes directly connect to the gateway or use multi-hop connections. The gateway provides a common interface which higher level applications and services can access the underlying sensor networks and their capabilities. When a new node is activated, the node context information is stored in the gateway repository. The goal of storing this information is to obtain a semantic description that other processes can exploit and infer the status and capabilities of each node. The information processing layer uses the data from the connectivity layer and from the context information to support query analysis and processing. To establish a reliable connection between sensor nodes and gateway, a method similar to the association and negotiation protocol in the IEEE 802.11 Standard’s negotiation steps is developed.

The details of the gateway architecture and the negotiation mechanism is discussed in [9].

In Figure 3 a mapping of the different layers in the gateway to the OSI model is illustrated. The connectivity layer in the gateway provides device connectivity via physical, datalink and network layers to a unified access layer. In the current work we support connectivity for the IEEE 802.15.4 capable nodes (the Operating system (e.g. SunSpot nodes) or in the protocol stack (i.e. TinyOs 6LoWPAN) level support). Incoming Queries are processed in the Information Processing Layer. The Application Layer in the OSI model is mapped to the Service Layer in the gateway design. The gateway provides Web service interfaces to represent the sensor nodes and their capabilities and data and to integrate the network data into higher level applications and services.

2.2. Sensor description model

As an upper level ontology, we use the SSN ontology from the W3C Semantic Sensor Networks Incubator Group and extend it to represent context information for the sensor devices in the gateway. The extended ontology represents information related to sensor instances and their deployment attributes. Each time a new sensor is associated to the gateway, a template for the sensor type is loaded and filled with the information that are the relevant to the node. We assume that the gateway plug-in developer for a particular sensor type will provide the template. If the template did not exist, the sensor node should send semantically annotated data according to the designated model as a part of handshaking and negotiation process. The SSN ontology allows to define attributes related to measurement capability of a sensor node, device features, and platform related attributes. The model extension includes the sensors context information. We introduce a new Entity “SensorContext” in the SSN ontology. SensorContext describes the sensors context in terms of available battery, deployment environment attributes, location, time and the attributes that can be specified for the sensor measurement capability in the SSN ontology. The following illustrates a snippet of a sensor context description (or in fact this is an instantiation of the the SSN schema ontology).

In the following section we describe the concepts of linked data and discuss how different sensor data descriptions are supported and published in the platform.

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11http://standards.ieee.org/about/get/802/802.11.html

12http://purl.oclc.org/net/unis/ssnExtended.owl
3. Linked data

Publishing data on the semantic Web with machine interpretable representations facilitates more structured and efficient access to the resources; however semantic descriptions without being linked to other existing data on the Web would mostly be processed locally and according to the domain descriptions (i.e. domain ontologies). Linking data to other resources on the Web enables obtaining more information across different domains. The linked data concept was initially introduced by Tim Berners-Lee in 2006 [10]. Berners-Lee suggested four main principles to publish linked data:

- using URIs as names for data,
- providing HTTP access to those URIs,
- providing useful information for URIs using the standards such as RDF and SPARQL,
- including links to other URIs.

Publishing annotated and interconnected data is the underlying principal of creating linked Web resources that is referred to as the Web of Data [10]. The Web of Data can be browsed and accessed as traditional HTML pages on the Web. However, in the Web of Data instead of HTML links between the pages, the resources are connected via links that can be queried and interpreted using discovery and search agents [11]. Linked data enables users to navigate between different data sources by following the data connection links. This allows the linked data consumers to start with one data source and then browse through a vast number of resources interconnected by machine interpretable links (e.g. RDF links).

The Web of Data is supported by the Semantic Web and in particular the Linking Open Data Community project in the W3C Semantic Web Education and Outreach Working Group\(^\text{13}\). The Linking Open Data Community project started in 2007 and as reported in September 2010 the data sets that have been published and interlinked consisted of 203 sets with over 25 billion RDF triples which are interlinked by around 395 million RDF links\(^\text{14}\). The project includes various open data sets available on the Web such as Wikipedia\(^\text{15}\), Wikibooks\(^\text{16}\), Geonames\(^\text{17}\), and WordNet\(^\text{18}\). Figure 5 shows the data sets that have been published and interlinked by the project\(^\text{19}\). In practice, the linked data published on the Web is RDF data that is accessible via HTTP interfaces. Recently some public and government organisations data has also been published as linked-data; for example the UK government provides linked data in different sectors [12] which can be queried via SPARQL endpoints\(^\text{20}\).

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\(^\text{13}\)http://esw.w3.org/SweoIG/TaskForces/CommunityProjects/LinkingOpenData

\(^\text{14}\)http://esw.w3.org/TaskForces/CommunityProjects/LinkingOpenData/DataSets/Statistics

\(^\text{15}\)http://www.wikipedia.org/

\(^\text{16}\)http://www.wikipedia.org/

\(^\text{17}\)http://www.geonames.org/

\(^\text{18}\)http://wordnet.princeton.edu/online/

\(^\text{19}\)source: http://richard.cyganiak.de/2007/10/lod/lod-datasets_2010-09-22_colored.png

\(^\text{20}\)http://data.gov.uk/sparql
mated decision making systems among many other applications. The linked sensor data can be queried, accessed and reasoned based on the same principles that apply to linked data. This creates an open platform to publish and consume interoperable sensor data.

4. Linked sensor data

Sheth et al. in [7] define semantics of sensor Web within Space, Time, and Theme attributes. There have been different approaches to provide semantic models for each of these attributes independently or in relation to sensors. Some of the common ontologies are SIMILE location ontology\(^{21}\), DAML location ontology\(^{22}\) for spatial attributes, OWL time ontology\(^{23}\) for time and common ontologies and vocabularies such as Cyc\(^{24}\), DBpedia\(^{25}\) for thematic data. In a previous work, we described annotating sensor observation and measurement data according to these attributes [13]. In this paper, we discuss publishing linked sensor data and association of this data to the existing resources and especially those that are currently a part of the Linked Open Data.

4.1. Spatial attributes

Location specific information for sensors could include specific geographical location attributes defined as longitude and latitude and/or high level concepts that describe the location in different terms and in relation to other domain concepts (e.g. postcodes). In the SWE Sensor Observation Service (SOS) [4] standard to provide sensor observation and measurement data, the descriptions include location attributes that are explained using GML\(^{26}\) elements. Patni et al. [14] describe a linked sensor data platform that uses location attributes in the OGC standards and associate them to high level location concepts that are available via the Linked Open Data concepts. In particular, we have used concepts referring to different locations selected from DBpedia and GeoNames. Figure 6 shows a SPARQL snippet to query a sample location from DBpedia.

![Fig. 6. A sample location query from DBpedia](http://linkedgeodata.org)

4.2. Temporal attributes

Temporal attributes in sensor data are those describing attributes such as time zone and measurement time-stamp. In this context, using common ontologies for temporal specifications enable linked data consumers to query and access temporal features of data using standard models and interfaces. There are also aspects such as freshness for querying the observation and measurement data or availability time for the sensor and network nodes that can be specified using temporal attributes. This attributes can be then processed and inferred by application and service level re-

\(^{21}\)http://simile.mit.edu/2005/05/ontologies/location
\(^{22}\)http://www.daml.org/experiment/ontology/location-ont
\(^{23}\)http://www.w3.org/TR/owl-time/
\(^{24}\)http://cyc.com/cyc/opencyc
\(^{25}\)http://dbpedia.org/
\(^{26}\)http://www.opengisgeospatial.org/standards/gml
\(^{27}\)http://linkedgeodata.org
sources to access the appropriate data or to can be used for service integration and planning purposes (i.e. by knowing when services will be available or to use it in service/data compensation processes).

4.3. Thematic attributes

Thematic data provides links between sensor data and domain knowledge in different applications. The attributes such as sensor type, description tags, type of observation measurement, features of interest and other more specific attributes including operational and deployment attributes describe sensors with domain knowledge. We use an ontology to provide more specific sensor descriptions such as those proposed in the SENSEI project [15] and device specific information according to the W3C’s Semantic Sensor Networks Ontology as described in Section 2.2. The high level concepts to specify sensor data are provided by referring to the Linked Open Data resources available on the Web. For this purpose, we use DBpedia resources to define sensor types (i.e. general types) and tags (general concepts and applications) and high level location descriptions are adopted from DBPedia and GeoNames. It is also worth mentioning that in many applications relying only on general sensor type definitions provided by community-driven vocabularies such as DBpedia will not be sufficient; however, in this paper we only demonstrate how linked sensor data can benefit from existing resources. Similar to location information, for more specific information, local and application/domain specific ontologies can be used to describe detailed attributes more precisely.

4.4. Sensor specific attributes

Sensor data does not only consist of spatial, temporal and thematic features. The sensor as a device and the sensing process have also more specific attributes and features. In addition to providing links between sensor attributes and other resources, there are approaches to annotate and link sensor observation services and also describe device dependent and process specific features of sensor data. In this context, Janowicz et al. [16] describe a semantic enablement layer on top of the SWE standards. Henson et al. [17] discuss construction of a Semantic Sensor Observation Service based on the SWE standards. There are several approaches that provide ontology based description for more specific sensor data such as those described in [2], [3], and [18]. There are also important issues such as search, discovery and fusion of sensor data and dynamic updates that are not in the scope of this paper. The SENSEI project white-paper provides a review on some of these issues and discusses possible solutions for some of these issues[19].

4.5. Re-visiting linked-data principles to publish linked sensor data

The four main principles described by Berners-Lee [10] are not mandatory guidelines to publish linked data; however, following these principles makes the linked data easily and efficiently accessible to consumers on the Web. In this section we revisit the guidelines and discuss them for publishing linked sensor data.

4.5.1. URIs and Naming:

By assigning URIs to sensor network descriptions, each sensor and/or node has a unique URI that refers to its descriptions. The naming of sensors can follow similar conventions that are used in HTML pages (or other resources on the current Web). The SENSEI project proposes a more specific guideline to define a Universal Resource Name (URN) for sensors. In the SENSEI project, the unique resource identifier includes administrative domains as the first part after the namespace identifier and then adds resource identifiers to the URN [19]. The following shows a sample URN using the SENSEI naming convention.

\texttt{urn:sensei:surrey.ac.uk:TeloSBSensorTS1:Temperature:SampleRate:3223a-86bca-0123-e123}

All resources in SENSEI are identified by a domain and the unique resource identifier is constructed using the domain name, sensor type and an internal unique identifier. We propose a similar approach for defining sensor identifiers; with a difference that in our linked sensor data the identifiers are defined as URIs. This to a large extent addresses the naming issues discussed in deployment and utilisation of large sensor networks. In this scenario all the resources are identified by a unique URI and access to the low level sensor nodes in the sensor networks are provided via the gateway components. The sensor network data (i.e. node and device status updates) and observation and measurement data can be then provided via HTTP level Web services and the sensor node description and attributes are available by referring to the linked description data (i.e. the node descriptions and status updates are not in the scope of this work and are not discussed in this paper).
4.5.2. Providing HTTP access:

The linked sensor data can be made available through HTTP access by simply publishing descriptions as Web documents or in a more efficient way, as linked data approach suggests, by providing SPARQL endpoints to query and access the data. Sensor observation and measurement data can also be made available through HTTP interfaces via sensor observation services. The SWE Sensor Observation Service (SOS) [4] defines a standard Web service interface for requesting, filtering, and retrieving observations and sensor system information. In [20] a service oriented middleware architecture for providing HTTP access to sensor observation and measurement data is also discussed. In Section 2.1, we discussed our gateway component that provides HTTP level access to the sensor data. The sensor node descriptions are also published as RDF data and we provide SPARQL endpoints and standard query interfaces to access this data. Sense2Web also allows users to publish RDF sensor descriptions according to other ontologies and models. The details of publishing RDF sensor data are described in Section 5.

4.5.3. Providing meaningful descriptions:

The sensor data in Sense2Web includes RDF descriptions according to ontologies designed to represent different features and attributes. We propose a two layer sensor data annotation. This enables sensor data annotation according to the above described models and also using some of the features to link the descriptions to other resources on the Web (and in particular Linked Open Data concepts). In Sense2Web, an RDF description captures basic attributes of a sensor and/or a node (i.e. spatial and thematic data) and uses publicly available linked data to create links to other resources.

4.5.4. Linking to other URI's:

To describe sensor data the instances for each attribute (i.e. property values) wherever it is applicable can be chosen from publicly available linked data. This enables construction of sensor descriptions that are already linked to other resources based on different features. We also propose using local ontologies and vocabularies to provide more specific descriptions and also allow users to add and associate existing RDF data, according to other ontologies, to the sensor descriptions. Including all this data and publishing it as linked RDF data creates a set of resources that some of their attributes are already described using other Web resources. This allows browsing and accessing the data by referring to different attributes. It also establishes a link between other RDF descriptions of the sensor data and the high level concepts in the semantic sensor network framework.

5. Sense2Web platform

Sense2Web enables publishing linked sensor data according to the four main principles discussed in the previous section. It enables users to publish their sensor description data as RDF triples, use other existing RDF sensor description data, link the descriptions to the existing resources on publicly available linked data repositories and make it available to the data consumers through SPARQL endpoints.

Figure 7 shows the user interface for publishing a new sensor description in Sense2Web. We use Jena API [21] to query DBpedia and other resources to obtain values for location, type and descriptive properties. We query the Linked Open Data resources and serialise the results using AJAX technology [22] directly to the page; so user can type a keyword and obtain relevant suggestions from on-line repositories. Figure 8 shows suggestions from DBpedia for a sample query, “Guildford” as a location attribute.

The submitted variables are stored in XML format and Extensible Stylesheet Language Transformations (XSLT) is used to transform the submitted data to RDF form. This makes generation of the RDF data flexible and less dependent to the current model. We construct the RDF data for sensor node descriptions according to a basic RDF structure that captures main properties of available sensors and link it to other RDF files that provide more specific properties according to common sensor ontologies. However, by using a dif-

28http://www.w3.org/TR/xslt20/
ferent stylesheet data can be transformed to another format or other namespaces based on different applications and requirements.

It should be noted that the properties identified in main the Sense2Web RDF descriptions are neither complete nor fixed. The system includes primary attributes to demonstrate the feasibility of publishing linked sensor data and it can be extended to include more specific attributes to describe sensor network data.

Figure 9 shows the main components for linked data publication in the Sense2Web platform and the interfaces to access the published data.

We use SDB\(^{29}\) a SPARQL database for Jena to store the RDF triples. To provide SPARQL endpoints, we use an open source SPARQL server for Jena called Joseki\(^{30}\). We have also implemented interfaces that enable users to obtain the query results in a different format such as XML, RDF and SPARQL protocol format\(^{31}\).

\(^{29}\)http://openjena.org/SDB/

\(^{30}\)http://joseki.sourceforge.net/

\(^{31}\)http://www.w3.org/TR/rdf-sparql-protocol/

5.1. Mash-up application

To demonstrate the linked data usage and integration of data from different sources we have created a mash-up application using Google Maps API\(^{32}\). For this application, we use the location attributes and retrieve geographical coordinates of the nodes by processing the Linked Open Data resource descriptions. The application retrieves related properties of the resources from the linked sensor data repository and lists available sensors and their properties through a Google Maps

\(^{32}\)http://code.google.com/apis/maps/
application. In the current demo, we only retrieve published nodes and show them in a map overlay. This can be extended to discovering other related resources such as nearby locations, districts and other related information available through browsing different links. Figure 10 shows some of the related data available for our sample query (“‘Guildford’”) from DBpedia.

Figure 11 demonstrates the application and shows available information for a sample sensor published according to our description model. In our sample, we create links between domain (i.e. thematic) level attributes of sensor data, type and keyword descriptions. In fact, if more public semantic data related to different attributes of sensor description is available, then more properties of sensor description can be linked to other resources. This will require more common ontologies to describe sensor types, sensor platforms, sensor measurement attributes, sensor devices, etc.

6. Conclusions and future work

This paper discusses construction of linked data from sensor data and in particular providing sensor descriptions and associating their attributes with resources on the Web. The presented work provides interoperable sensor data descriptions and facilitates publication of this data as linked data. We describe our platform and discuss how existing Linked Open Data resources are used to describe spatial and thematic attributes of the sensor descriptions and to link them to the Web data. We discuss using stylesheets to transform the annotation data to different designated sensor description formats such as W3C SSN ontology representations. The paper describes the linked data principles and we describe the implemented prototype. A demonstration of the framework following the linked data principles and using a mash-up application is also provided.

The future work will focus on defining and integrating different sensor platforms to the system. This will include providing sensor and service discovery mechanisms and evaluating the scalability of the platform. Providing reasoning methods and processing the linked data descriptions to integrate sensor data into business applications and smart environments will also be a part of the future work. We plan to define description models for network nodes and servers to facilitate autonomous management of resources in the sensor networks and to represent these descriptions as linked data in the platform.

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