A Practical Approach to an Integrated Citizens' Observatory: The CITI-SENSE Framework

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Abstract. The prevalence of research projects that include a focus on Citizens' Observatories (CO) is on the rise, and this increase has led to many initiatives, most notably 'Eye on Earth' which aims to provide a platform which will "facilitate the sharing of environmental, societal and economic data and information, provided by the diversity of knowledge communities, to support sustainable development." This statement covers a whole range of CO communities and projects that can be said to share a common goal, but in many other ways are quite diverse and, from an architectural and Shared Environmental Information System (SEIS) perspective, may focus on different aspects. This paper will seek to provide a practical approach to creating an integrated Citizens' Observatory based on the work undertaken in the EU FP7 CITI-SENSE project and following the CITI-SENSE Framework (CSF).

Keywords: Citizens' Observatories, Environment, Infrastructure, Platform, Architecture

1 Introduction

The key to protecting and improving our environment is in the hands of the many, not the few. Although our political, economic and administrative structures may be designed to tackle our environmental concerns through scale and strategic decisions – it often leaves citizens as unused and silent observers [1]. The Environmental data products and services created in the CITI-SENSE project [2] (or indeed, any project with a strong Citizen Observatory focus) are intended to change this. Although they may be consumed by a varied group of stakeholders ranging from large government organizations with enterprise systems, to SMEs and environmental scientists, ultimately it is the citizens in their home with consumer devices such as mobile phones or laptops that we wish to target. In order for any such project to be successful it is paramount that information is published in the most accessible form according to the user, their capabilities and their expectations. Since users vary in their level of understanding and interpretation of environmental information, then underlying this basic principle is the very real challenge of developing services or products that can cater to them. For example, providing citizens with near real-time environmental data, generating reports to municipalities and regulating bodies, and providing state-of-the-art monitoring is all part and parcel of the expectations imposed upon those who provide the ICT (Information Communication Technology) services that support the complex world of environmental data monitoring, analysis and dissemination. And while these objectives may not appear to be conflicting, they do require quite distinct methods and approaches in terms of data analysis, modeling and presentation; the correct approach being dictated by who the data is for, what that user understands and what they expect to get from it. Recognizing that there is no such thing as a typical ‘end user’ or rather that end users are quite different both in terms of expectations as well as knowledge and expertise is the first step in developing a Citizens’ Observatory, as these requirements will drive the functionality and service design that is intended to cater to them.

Within the topic ENV.2012.6.5-1 “Developing community-based environmental monitoring and information systems using innovative and novel earth observation applications”, EU FP7 framework currently funds five projects with a clear focus on Citizens' Observatories. These are: CITI-SENSE [2], WeSenseIt [3], Cobweb [4], CitClops [5] and OMNISCIENTIS [6]. The environmental domains differ widely between these projects, covering air quality, water management, biosphere reserves, coast and ocean optical monitoring and odour monitoring, respectively. However, as different as the subject of their data may be, their overall goal of creating an interactive and vibrant environment where users are encouraged to participate with their own observations is likely quite similar, sharing many of the same goals. However, this paper’s focus is primarily on describing the development of an architectural approach to supporting citizens' observatories and their users from the perspective of just one project, although it will draw on the experiences and lessons learned from several EU FP6-7 projects that are now completed. The subject project that we take our framework from is the FP7 CITI-SENSE project, part of the ENV.2012.6.5-1 topic, mentioned above.

2 What is a Citizens' Observatory?

At this time, there is no consensus exactly on (i) what a CO is; (ii) what it should do, (iii) who it should be for and (iv) how it should be made. According to Liu, et al. [7], a CO is defined as being “citizens observing and understanding environment related problems, and more particularly as reporting and commenting on them.” While we agree with this general statement, it does not indicate any kind of approach or methodology. Indeed, even the definition of exactly what 'citizens' means can be discussed. But, as short and to the point as that definition is, careful consideration of it does clearly reveal three core components that underpin its objectives. We can define these broad objectives as: raising awareness, initiating dialogue and data exchange. These points can be considered as the three pillars that support a Citizens’

Observatory. As we discussed in the introduction, how these pillars relate to the stakeholder's experience, expertise and expectations are clearly important. In the following section, we briefly discuss them in turn.

2.1 Raising awareness

Information is available to us in a myriad of ways and from many sources. Via newsprint, radio, television, online portals and mobile devices. In fact, there is so much information it is sometimes hard to keep track of what we need, or even to really understand what we need to know. At the recent 2013 Green Week conference, the European Environment commissioner, Janez Potočnik reinforced this when he stated that "We have learned that public awareness is of key importance for the implementation of existing air policy, as well as for the success of any future air pollution strategy" [8]. Clearly, getting the useful 'message' across to the public, in the right way and thereby effectively raising public awareness, is critical. The first criterion therefore is to determine who you want to get your message to, and then targets those users in a way that ensures a certain level of interest engages their desire to know more.

In previous projects (ACCENT [9], HENVINET [10], and ENVIROFI [11]) we have attempted to engage users through various campaigns, including mass emailing, printed media such as brochures, online video presentations and workshops in the Café Scientifique format. These methods did generate a sufficiently moderate number of public users interested in knowing more about the project topics but ultimately they did not create a self-sustaining community of users willing to engage or participate long term in a community forum based on a social networking style platforms. So while it could be argued that we were moderately successful, it was clear that we did not really create a viable, sustainable community. What was missing was the emphasis on knowledge transfer. Raising awareness is not just about alerting the public or recruiting users; it is just as much about helping those users understand the issues, problems and concerns relating to the environment so they can make informed decisions of their own. And while these platforms did include expert users who could answer questions about environmental issues, this does not automatically translate to true knowledge transfer. An additional factor is to ensure that our communities' opinions, thoughts, questions, etc., are not only heard/informed, but valued and just as importantly, are seen/involved to be valued. To do this, we needed to provide a platform for creating a dialogue with our users.

2.2 Initiating dialogue

Successful multi stakeholder dialogues are critical to ensuring a deeper level of interest from stakeholders, especially the general public. At the most basic level, these can take the form of peer to peer as well as public to expert (which includes science and policy) so any forum for discussion needs to have a comprehensive membership drawn from a multidisciplinary volunteer 'workforce'. Not only this, but the members must be consistently active. Nothing kills a communication portal quicker than low levels of active participation. Only if regular activity, from a varied group of users is achieved are you likely to see sustained growth over time, as more people begin to participate than fall away. It cannot be overemphasized that this is not a place for passive participation and that static information portals guarantee a quick demise. Social media applications can be employed as a platform for initiating dialogue but in itself, this is ultimately insufficient. It is critical to move to a more advanced level, since multi-stakeholder dialogues are more than just question and answer or discussion forum style communication as they must include technology based information gathering and exchange systems. These can include sensors as well as personal, subjective observations from the users, which will create a much broader canvas for information gathering and of course, data exchange.

2.3 Data exchange

Data exchange is much more than just pushing data to users and goes beyond the sharing of ideas or questions, etc. In a Citizens' Observatory context, this must include a variety of VGI (Volunteered Geographic Information) observation types, in addition to personal observations on an array of topics, such as physical wellbeing, perceived environmental effects and even personal opinions. Key to this is that the citizen is encouraged to collect and provide data input regularly and finds value in the way that this information is used. The citizens' peers may also find value in this data and be further encouraged to make their own observations available. An important aspect is that all data, not just electronic sensor data, has a geo-temporal marker.
The wider public is now in a position where micro sensors can be accessed in increasing numbers due to advances in technology and lowering costs. An individual might purchase sensors for any number of reasons, and tying them into a national (even international) collection, storage and dissemination platform is becoming increasingly possible. However, while this results in more data being generated it is not necessarily engaging the users themselves who might be entirely passive data providers. An important aspect of the Citizens' Observatory concept is the realization that citizens are now potentially walking, talking sensors and their inputs (covering a wide spectrum of data types) are potentially very useful. For example, pollen data is generally very limited, so major generalizations are often made about the prevalence of pollen in any given area (the further from measurements stations, the more this is true). Therefore, if individuals reported the presence of particular types of pollen (there are about thirty that cause allergies) in a specific area, then this could be of great interest to others who also have an allergic reaction to that particular pollen type. Therefore engaging citizens in providing personal observations on their perception of the environment can have beneficial consequences for others, which will further encourage others to participate with their own observations as well. Finally, presenting information that combines heterogeneous data sources which includes VGI data allows the stakeholders, in particular public users, to see just how their individual contributions add to the value chain, ultimately creating a reinforcing mechanism that will help to create a self-sustaining community.

2.4 Applying the three pillars

Within CITI-SENSE there are nine pilot cities that will employ one or more end user ‘products’ developed within the project. These products are separate from the various support services, such as GIS, WMS, Modeling, etc that actually enable the products to function. The products fall into two basic types: a) a web application and b) a smart phone/mobile device application. For the web applications, these take the form of web portals with dynamic content (beyond the usual database driven CMS). The dynamic content includes visualizations of sensor data from various locations. For example, one of the pilots places varying sensors in school classrooms. The data generated by the sensors will be stored in a database, and ultimately displayed on the web portal in near real-time. The visualization of the sensor data is handled by widgets that fetch the data from the database, and display them in accordance with the pilot officer's wishes (eg. graph, 1 month historic data, 3 months, etc). This can be viewed as the archetype for all the web portals, since they all work in much the same way regardless of location, sensor or data source.

The smart phone applications are, naturally, a little different. They also display sensor data to the user, but due to the nature of the platform, they demand a much more interactive approach from the user. The web applications can display more data, with associated descriptions, content, etc, because they have much more 'real estate' in which to work. The smart phone applications suffer from having a relatively small screen area, and consequently, much more care is needed in presenting the data to the user, or rather, in choosing just what data to present first. In addition, because the mobile devices have GPS capability, several of the pilots leverage this by tracking the movements of the user and storing that as additional data alongside any sensor data generated by the user or from attached sensors, or from the phone itself. Since several smart phone applications will be developed for the city pilots, it is obviously important to develop a platform that enables them to share common libraries and where possible, re-use of code. This is a core objective when designing the architecture which must enable end products which serve entirely different users, with different needs and expectations and levels of understanding.

Since the smart phone applications cover a variety of uses, from simply displaying textual information, to tracking the user's movements in order to provide assessments on UV exposure, to using meteorological sensors which communicate with the phone via Bluetooth and also detect motion from gyroscopic functions within the phone itself which enables the calculation of movement, it is essential that the architecture is both flexible and scalable to be able to adapt to any changing demands as they occur. Both data delivery platforms, web and mobile, push data to the user, but both can receive data from both the end users as well as (in the case of the mobile devices) attached/connected sensors. The interactive nature of a web or phone application is ideal for generating VGI, or observations of a personal or subjective nature. These are observations that the user can make on his perceptions of the environment and or health and well being. Further, directed requests for data can be made through the use of questionnaires which the user can complete and submit, thereby generating more data of a subjective nature, but with an aimed focus.

These approaches are all used in the CITI-SENSE project where there is a wide variety of Test Cases employing sensors in schools, in the hands of users as they go about their daily routines (UV for example) and sensors that are part of the mobile device, or even the user himself. An example of the latter is the method taken by the city pilot which is investigating noise, thermal comfort and outdoor spaces and which uses a combination of human as sensor, Smartphone as sensor and both VGI and directed data request (quiz). When taken as a whole, the CITI-SENSE project covers a broad spectrum of requirements where every pilot is a Citizen Observatory in its own right. Key to this ambitious objective is, of course, an underlying architecture that is both flexible and adaptable.

3 Developing a Framework

In this section we describe the CITI-SENSE Framework, which is based on combining a life cycle perspective of the services needed for a Citizens' Observatory with an architectural perspective of the services and components that can support this, in accordance with the SDI description approach of CEN/TR 15449 and ISO 19119.

This life-cycle based perspective facilitates the identification of enablers with both a service centric and data centric viewpoint. The project makes use of components which have been identified in a recent activity from the European Committee for Standardization (CEN) and Technical Committee (TC) 287 for building a reference model for spatial data infrastructures (SDI) [12], see Figure 1.

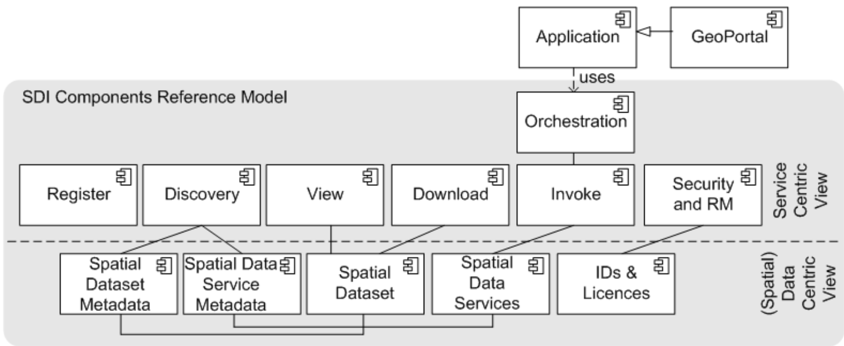

Fig. 1. Core Components of the SDI Reference Model ([11], modified).

The primary organizing structure is determined by the following generic core life cycle components (corresponding to the service centric view in the figure above):

- *Register*: for describing and publishing resources.
- *Discovery*: for searching for and discovery of resources.
- *View*: for visualizing of resources.
- *Download*: for downloading and exchanging resources.

- *Invoke*: for interacting with resources.
- *Orchestration and Composition*: for providing aggregated resources including in particular workflows for service composition.
- *Security and Rights Management*: for managing access rights to resources.

Related to the data centric and service centric view shown in figure 1, we illustrate the requirements of the environmental usage area. First, we define the roles, as part of overall added-value chain. Then we define the stakeholders, before applying the TR15499 framework to the project's architecture. In doing so, we provide a bridge between practical environmental applications and the wider political framework. The presented findings could equally be applied to other geospatial and non-geospatial domains beyond the environmental domain.

3.1 Roles and Value Chain of Environmental Knowledge Generation

Analyzing the requirements of eEnvironment services for the terrestrial and atmospheric sphere, we define a total of six roles, which may contribute to the generation of environmental knowledge [13]:

1. *Observer*, being the initial source of information about the environment. This may be a sensor measuring weather conditions to a citizen making an observation.
2. *Publisher*, making a resource, such as an observation, discoverable to a wider audience, e.g. by providing required resource descriptions (metadata).
3. *Discoverer*, being the entity that finds a resource, e.g. pollen occurrence data, based on all available descriptions.
4. *Service Provider*, making information or an environmental model accessible to (and usable by) the wider audience, e.g. by offering a standard based service for data download.
5. *Service Orchestrator*, being responsible for combining existing services in a way that they create information for a distinct purpose, i.e. environmental application focusing on a particular sphere, such as air quality.
6. *Decision Maker*, consuming an environmental application in order to retrieve decision supporting material and making a final decision based on the information available.

Consequently, the process workflow can be summarized as in the figure below (Figure 2). Notably, following this workflow, services may get published in order to serve as building blocks for more complex eEnvironment solutions.

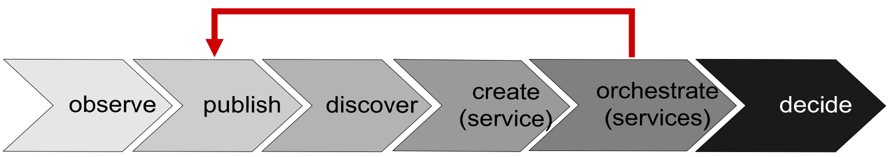

Fig. 2: Added value chain of environmental knowledge generation [12]

3.2 Overview of Stakeholders

The tasks identified above (section 3.1) are performed by a variety of individuals and organizations. These can be further defined as:

- *Citizens* of a particular social, political, or national community;
- *Environmental agencies* on sub-national, national and European level;
- *Public authorities* of national and regional and other level;
- *Industries* from the primary, secondary and service sector;
- *Platform providers* offering frameworks on which applications may be run;
- *Infrastructure providers* offering physical components and essential services;
- *Sensor network owners* holding the sensor and basic communication hardware.

	observe	provide	discover	create	orchestrate	decide
Citizens	x	x	x	x	x	x
Environmental agencies	x	x		x		x
Public authorities		x		x		x
Industries			x	x	x	x
Platform providers				x		
Infrastructure providers				x		
Sensor network owners	x	(x)		(x)		x

Tab. 1. Added-value chain of environmental knowledge generation [12].

Table 1 provides an overview of the manifold mappings between these stakeholders and the different roles in the value chain of environmental knowledge generation. Notably, citizens can play all roles within the value chain of environmental knowledge generation.

3.3 Applying the TR 15449 Architecture to CITI-SENSE

The life cycle based enablers and relevant applications can further be described in terms of their architectural components and enablers/services. The following figure shows how the different types of enablers can be related in the context of a complete end-to-end ICT architecture.

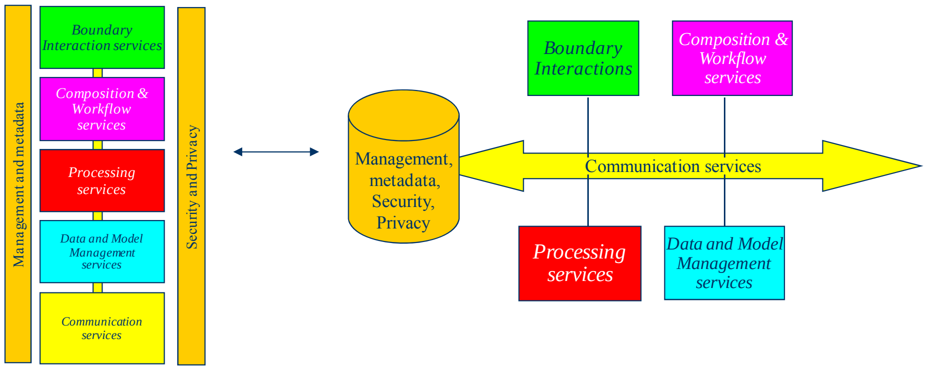

Fig. 3: Relationship of enablers in both a layered and a bus architecture

Figure 3 shows the relationship of different enabler categories both in a layered architecture and also as a bus architecture. The taxonomy of the enabler types is in accordance with ISO 19119 Geographic information – Services, clause 8.3. [15]. The approach is to define both generic domain independent and specific enablers, such as geospatial and environmental specific enablers, in each of the following six groups, color coded in the figure: Boundary Interaction Enablers, Workflow/Task Enablers Processing Enablers, Model/Information Management Enablers, Communication Enablers and System Management and Security Enablers.

4 A Practical Approach to the CITI-SENSE Architecture

The CITI-SENSE project is developing an architecture based on state-of-the-art, open standard components, defining a Citizen Observatory ontology and implementing a series of nine empowerment initiatives that validate the architectural design.

4.1 Use of Ontologies and Linked Data within CITI-SENSE

Too often information is made available as lists of figures or spreadsheets that only experts can interpret. To encourage and benefit from participation of a broad spectrum of users, we need to present our information in a way everyone can understand [18].
One of the objectives of CITI-SENSE is to create city observatories across nine locations in Europe and the near East. As described in section 2.4, diverse pilots have been defined and will be deployed. But what to do with the data they generate? How can this data be gathered and disseminated in a standard way so citizens and stakeholders can make use of it? Visual analytics is, of course, a key component, but how the data is stored and accessed, is important too.

Linked Data is the technology that allows publishing of data in a standardized way and linking to other data sources that complement it. For instance, while a CITI-SENSE pilot is gathering information about thermal comfort in a public park (objectively measured with sensors and subjectively by asking people for their impressions), we can also link this information with the current weather forecast, the wind speed or even the humidity measured by weather stations in the surroundings, thus providing a wider context for the data.

The ontology developed in CITI-SENSE is used to annotate the data gathered by sensors, modelled data, VGI and answers to questionnaires, with the aim to publish this annotated dataset under the Linked Data paradigm as open data, linking it to other linked datasets in the Linked Open Data Cloud.

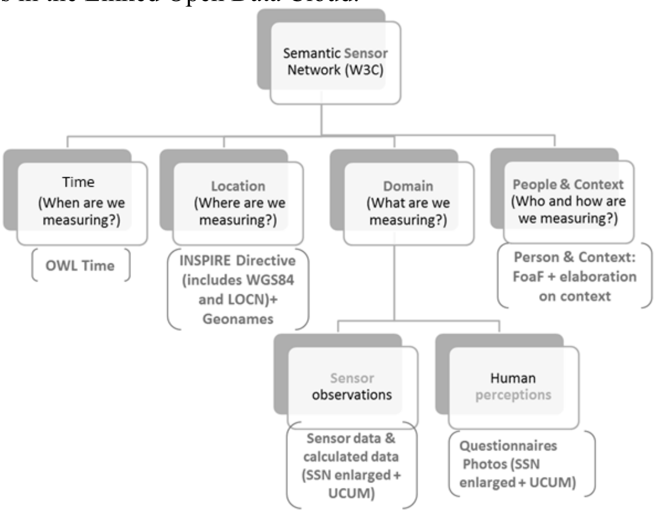

Fig. 4: Ontologies in CITI-SENSE

The Citizens' Observatories ontology adopts the Semantic Sensor Network (SSN) [19] ontology as the upper ontology. The SSN ontology is considered to be the de facto standard in the sensor world, so this ontology ensures future scalability of the CITI-SENSE knowledge domain as well as providing possible links to other existing efforts in sensor data gathering and publication. However, the SSN ontology leaves the observed domain unspecified, so other ontologies have been selected and aligned with the SSN ontology. Each additional ontology has been selected to address a concrete need:

- **When are we measuring?** This is modeled by the OWL Time ontology, a W3C-recommended ontology based on temporal calculus, that provides descriptions of temporal concepts such as instant and interval and which supports defining interval queries such as within, contains, and overlaps.
- **Where are we measuring?** The European INSPIRE Directive defines how the different locations should be modelled. This includes two aspects: the environmental monitoring facility as a spatial object in the context of INSPIRE and Observations and Measurements linked to the environmental monitoring facility.

- **What are we measuring?** This covers the CITI-SENSE knowledge domain and is represented by the requirements coming from the CITI-SENSE empowerment initiatives.
- **Who and how are we measuring?** The citizens actively involved in sensor measurements are also an important part because their social and personal context (e.g. age, occupation) can influence the analysis of the gathered sensor data.

The Citizens' Observatories' composite ontology provides the vocabulary to annotate the available resources at each pilot: the description of the place where to perform the observations and the person in charge of such observations, to describe the different sensors and their measurements as well as the calculated data values from sensor data. The ontology has been implemented following the network ontology approach, trying to re-use as much as possible existing efforts in the ontology, linked data, sensor and Internet-of-Things (IoT) worlds. This can easily be seen in our efforts to be conform with the European INSPIRE directive from which, data specifications relevant to CITI-SENSE, have been implemented: Geographical Names, Utility and Governmental Services, Buildings, Addresses and Land Use.
The CITI-SENSE ontology is ready to annotate datasets with sensor observations, modeled data, metadata on people in charge of the observations and location, amongst other things, to be published under the Linked Data paradigm in the Linked Open Data Cloud. Thanks to the reuse of well-known and widely used ontologies such as the SSN and GeoNames, the links to existing published datasets are possible without modifications of the ontology.

The Citizens' Observatories ontology is open for future evolution where new sensors types, measure types or unit of measures may be required, without needing to modify of its core structure, only enhancing it with new instances.

4.2 An Open and Standards-based Architecture

The CITI-SENSE architecture has been designed around the concept of a centralized data platform (the "CITI-SENSE Platform"), which ingests data from a variety of data providers and provides access to this data via a range of web services and interfaces each aimed at a specific stakeholder domain.

The diagram (below left) shows a high-level enterprise viewpoint of the overall architecture, while the digram on the right shows and Information Viewpoint which clearly demonstrates the technologies that support the high level overview. Both diagrams show the various data providers on the left-hand side, the CITI-SENSE Platform at the core and the data consumers on the right.

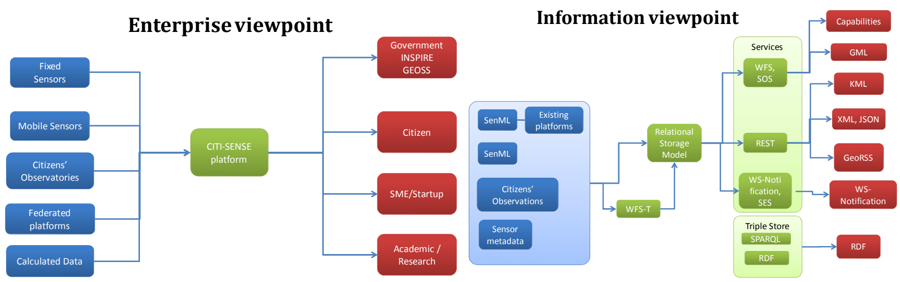

Fig. 5: Enterprise and Information viewpoints of the CITI-SENSE Architecture

The architecture of the CITI-SENSE Platform is built on open standards, and not constrained to any specific proprietary data exchange format or vendor specific data repository, thus making the Platform accessible via open standard interfaces and web services. Figure 6 shows the CITI-SENSE Platform architecture, where three different data providing platforms have been identified:

1) Providers that already have an existing platform for receiving, storing, post-processing and publishing data.
2) Providers that can collect or create the data but have no mechanism for storing, post-processing or publishing data.
3) Providers that have developed an algorithm, service or application that can create derived or value-added data products from the original observation data. They need to be able to access the original data, have a mechanism for storing and publishing the derived or value-added data. Additionally they may want to run an algorithm, service or application on the CITI-SENSE architecture.

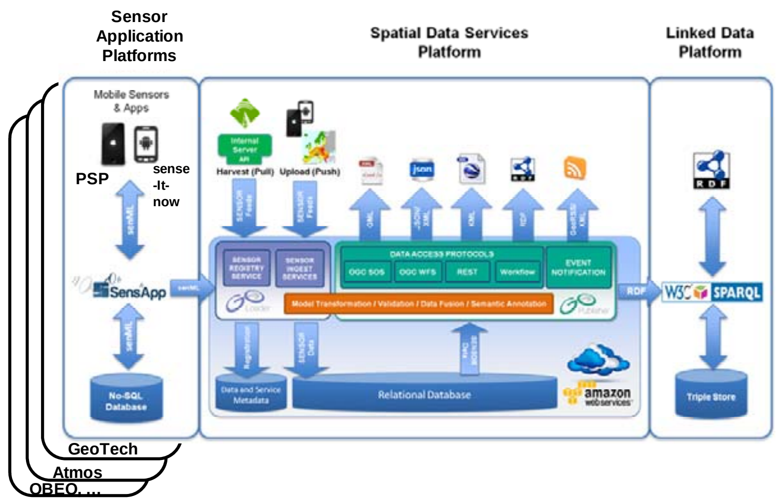

Fig. 6: - CITI-SENSE Architecture for sensor and data management

The CITI-SENSE architecture therefore consists of three distinct components, or platforms, that are all developed on standards-based technologies:

1) **Sensor Application Platforms** (W3C/OGC) – From various sensor platform providers, with associated input services and apps.
2) **Spatial Data Services Platform** (OGC/INSPIRE) – Implemented by GO Loader and GO Publisher and to be deployed using the Amazon Web Services (AWS) cloud infrastructure.
3) **Linked Data Platform** (W3C/OGC) – Using CITI-SENSE ontology for annotation and a Linked Data server to publish the dataset in the Linked Open Data Cloud.

SensApp is an open-source service-based application used to store and exploit data collected by the Internet of Things (IoT):

- Application can registers sensors, stores their data.
- SensApp notifies clients with newly arrived data.
- A third-party application is provided to visualize data.

SensApp offers web services to upload, from smart phones or other data gathering mechanisms, sensor data or extrapolated data to a repository. The data gathered by SensApp and other sensor platforms is loaded by the GO Loader component into the cloud-based centralised data repository.

GO Loader supports the configuration of enterprise-level relational databases and the loading of data delivered in XML and its geographic equivalent, GML. GO Loader's 'schema aware' technology means it can automatically adapt itself to any XML and GML application schema. GO Loader is responsible for the ingestion of data into the centralised data repository and supports data provided in a number of standard data specifications adopted in the CITI-SENSE project such as SenML (W3C), SensorML (OGC), Observations and Measurements (ISO/OGC) and INSPIRE Environmental Monitoring Facilities.
The GO Publisher software is used for making the stored data available via a number of open standard web interface technologies, such as Web Feature Service (WFS), Representational State Transfer (REST), Rich Site Summary (RSS) and Event Services. GO Publisher transforms the data from its SQL format into standard encoding formats as XML, GML and JSON.

5 Conclusion

The CITI-SENSE project is quite unusual in that it is not a single Citizen Observatory, but rather a collection of nine independent and in many cases, unrelated initiatives that may, or may not share resources and data. While this does pose difficulties, it also ensured that when developing an architecture to accommodate these different end points we were forced to address the question of creating a common platform from the very start. Naturally, this led to the adoption of existing standards, technologies and methodologies in order to not "re-invent the wheel" such as ensuring compliance to GEOSS, Linked Open Data, the INSPIRE Directive, etc, as well as re-using generic enablers developed in previous projects, such as SensApp.

The CITI-SENSE Framework can be said to be comprised of the following major components; its architecture, its products and citizen engagement through the 'three pillars'.

The three pillars approach provides a basic starting point for interacting and engaging with the public covering the aspects of raising awareness, initiating dialogue and data exchange. Supporting this is the work on product development which describes the core objectives for the various observatories, identifies commonalities and provides initial mock-ups. In this way, the CITI-SENSE Observatories have begun to take shape.

Although still at a relatively early stage in the project, we have already implemented some of the fundamental building blocks necessary for the foundation of the CITI-SENSE Framework. Our experience has shown that integration of existing infrastructures is not just desirable but entirely possible, as demonstrated by the inclusion of SensApp, GO Loader/GO Publisher and the Linked Open Data Cloud. The adoption of internationally recognised open standards for exchanging data allows data and services to be truly interoperable.

We have designed the architecture towards enabling services for 3rd party consumption in order that external users, willing to make use of the CITI-SENSE Framework, will find a variety of connection possibilities. From the point of view of a data provider, the CITI-SENSE Framework offers web services for data ingestion. As a data consumer, the framework can be seen as a pool of data access protocols and visualization widgets. A common repository for real time raw and/or derived sensor data has been developed but in addition a repository for data using different standards is also necessary. Consequently, new initiatives coming to join CITI-SENSE should be seamlessly integrated.

Further, we see the value that the Open Linked Data Cloud provides as it enhances our data through its ability to link datasets. In addition, the Linked Data paradigm provides a standard way to expose, share and connect data on a global scale.

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References

[1] Global citizen observatory - The role of individuals in observing and understanding our changing world (European Environment Agency, 2009): http://www.eea.europa.eu/pressroom/speeches/global-citizen-observatory-the-role-of-individuals-in-observing-and-understanding-our-changing-world
[2] CITI-SENSE – Development of sensor-based Citizens' Observatory Community for improving quality of life in cities, http://www.citi-sense.eu
[3] WESENSEIT – Citizen Water observatories, http://www.wesenseit.com
[4] COBWEB – Citizen Observatory Web, http://cobwebproject.eu
[5] CitCLOPS – Citizens' observatory for coast and ocean optical monitoring, http://www.citclops.eu
[6] Omniscientis – Odour MoNitoring and Information System based on CItizEN and Technology Innovative Sensors, http://www.omniscientis.eu
[7] Liu, H-Y., Kobernus, M., Bartonova, A., et al. Conceptual approaches to an integrated citizens' observatory: supporting community-based environmental governance (manuscript).
[8] Raising air pollution awareness 'of key importance'. Available on http://www.airqualitynews.com/2013/06/10/raising-air-pollution-awareness-of-key-importance/
[9] ACCENT – Atmospheric Composition Change – the European Network of Excellence, http://accent.nilu.no
[10] HENVINET – Health and Environmental Network, http://www.henvinet.eu
[11] ENVIROFI – The Environmental Observation Web and its Service Applications within the Future Internet, http://www.envirofi.eu.
[12] European Committee for Standardization (CEN): TR15449 Geographic information — Spatial data infrastructures — Part 1: Reference model. Technical Report (2011).
[13] Schade, S., Fogarty, B., Kobernus, M., Schleidt, K., Gaughan, P., Mazzetti, P. and Berre A.J.: Environmental Information Systems on the Internet - A Need for Change. In: Hřebíček, J., Schimak, G., Denzer, R. (eds.) ISESS 2011. IFIP AICT, vol. 359, pp. 165–172. Springer, Heidelberg (2011)
[14] The European Parliament and of the Council: Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE). Official Journal on the European Parliament and of the Council (2007)
[15] Commission of the European Communities: Communication COM(2009) 223 - GMES and its initial operations (2011 - 2013). (2009)
[16] Commission of the European Communities: Communication COM(2008)0046 - Towards a Shared Environmental Information System (SEIS). 2008/0046 (2008)
[17] Group on Earth Observations (GEO): The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan. (2008).
[18] Semantic Sensor Network Ontology www.w3.org/2005/Incubator/ssn/ssnx/ssn