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Leveraging the Future Internet for the Environmental Usage Area

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Abstract

In order to address part of today's grand scientific challenges and political agendas related to future Information and Communication Technology (ICT), the Information Society and Media Directorate General of the European Commission provided a novel scheme for innovation projects funded by the European Commission: the Future Internet Public-Private-Partnership (FI-PPP) as part of the Seventh Framework Programme for research and technological development. Eleven projects addressing the first of three intended program phases have been launched in Spring 2011. They comprise a large project dedicated to core Future Internet (FI) technology that is called FI-WARE; eight Usage Area projects, which deal with the requirement capture and functional component specifications of diverse application domains of the FI; and two support actions, one for capacity building, the other for collaboration support within and beyond the FI-PPP Programme. This paper explains the inner workings of the FI-PPP Programme, especially in relation to the Environmental Usage Area project, called ENVIROFI. This paper explains the overall relevance of the FI-PPP in terms of future eEnvironment services and Public Sector Information in Europe. It also outlines how the required contributions to the FI will be implemented, especially by detailing the interaction between ENVIROFI and FI-WARE. An outlook to a possible future of environmental ICT in Europe is included.

1. Introduction

The Future Internet Public-Private-Partnership (FI-PPP) Programme is an experimental research program of the Information Society and Media Directorate General of the European Commission (DG-INSFO) as part of the recovery package. The FI-PPP urges short delays between the project proposal and project start, demands strong co-operation among the research projects, and carries the opportunity to develop the initial ideas into products to be tested in large scale trials for the most successful consortia. The FI-PPP addresses the key societal challenges stated in the Digital Agenda for Europe (ec.europa.eu/information_society/digital-agenda) and in the Innovation Union (ec.europa.eu/research/innovation-union) flagship initiatives.

The central project of the FI-PPP Programme is called FI-WARE (www.fi-ware.eu). It comprises a consortium consisting of major European Information and Communication Technology (ICT) organizations and aims at establishing the *Core Platform* for Future Internet (FI). This Core Platform features a consistent set of components, so called *Generic Enablers*, allowing: (1) creation, publishing, managing and consuming the Future Internet services; (2) deploying the Future Internet services on the cloud, i.e. using cloud computing technologies; (3) accessing, processing and analyzing massive data streams, as well as semantically classifying them into valuable knowledge; (4) leveraging the ubiquity of heterogeneous, resource-constrained devices in the Internet of Things; and (5) accessing the networks and devices through consistent service interfaces.

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In order to ensure that the Core Platform and Generic Enablers are not only capable of meeting the requirements of arbitrary Usage Areas, but are indeed accepted by real users, FI-WARE shall closely work on establishment of the requirements on and development of the Generic Enablers with eight Usage Area FI-PPP projects and the communities these projects represent. In addition to the provision of requirements and the development of the prototype applications on top of the Core Platform, these projects are expected to contribute to so-called *Specific Enablers*, that is, add-on components compatible with the Core Platform and re-usable for certain classes of applications.

The Digital Agenda for Europe, which explicitly mentions the sensor web as one of the central enabling technology for eEnvironmental/eGovernment services in Europe, and directives on Public Sector Information (PSI) clearly motivate a Usage Area on the environment. The ENVIROFI (www.envirofi.eu/) project aims at representing the know-how and interests of this Usage Area, by following two main goals: (1) to 'Envirofy' the Future Internet, that is, to assure that the FI applications can easily use the environmental data and services; and (2) to make the Core Platform functionality available in environmental applications (Figure 1).

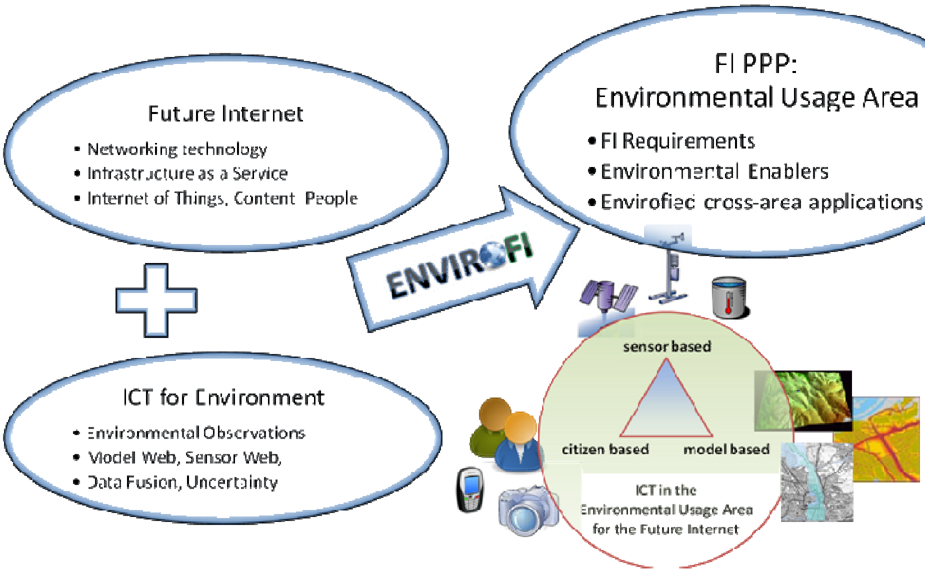

Figure 1: ENVIROFI links the Future Internet and the Environmental Usage Area

The paper at hand, for the first time, presents the basic ideas of FI-PPP, FI-WARE and ENVIROFI together in an integrated and comprehensive form. Apart from informing the environmental community about these important activities, the intention of the paper is above all to animate the environmental stakeholders to seize the opportunity for both raising the additional requirements on the Future Internet infrastructure, as well as to advertise the environmental resources which could be used in 'envirofied' applications within and beyond the FI-PPP.

The required background is presented in the section 2, followed by examples of environmental applications as they are and as they might be in the (near) future (section 3). Section 4 presents FI-WARE and gives a preview of its offering to the environmental Usage Area. Section 5 analyses the offering of ENVIROFI and, more generally, of environmental Usage Area. We conclude the paper by a summary of the preliminary status and an outline of future activities of the FI-PPP (section 6).

2. Background and Scenarios

This section provides details about the FI-PPP and the funded projects, some background to motivate the Environmental Usage Area, and a few envisioned scenarios regarding environmental information.

2.1 The Future Internet Public Private Partnership

FI-PPP is part of the Framework Programme 7 of the European Commission; more precisely of the ICT Work Programme 2010-2011. Its objectives are two-fold: (1) to increase the effectiveness of business processes and of the operation of infrastructures supporting applications in sectors such as transport, health, or energy; and (2) to derive possible innovative business models in these sectors, thus strengthening the competitive position of European industry in domains like telecommunication, mobile devices, software and service industries, content providers and media.

FI-PPP follows an industry-driven, holistic approach encompassing research and development on network and communication infrastructures, devices, software, service and media technologies, as well as their experimentation and validation in real application contexts. It brings together the demand and the supply sides, and also requires involving users early into the research lifecycle. The platform to be developed will thus be used by many actors, in particular by Small and Medium Enterprises (SMEs) and public administration services, to validate the technologies in the context of smart applications and their viability to support user driven innovation schemes.

The FI-PPP Programme is based on a three-phased approach with four tightly related objectives, or building blocks (Figure 2):

- the technology foundation, also referred to as the Core Platform, should provide a platform to support Generic Enablers in an open and trusted way;
- the use cases and trials aim at identifying these Generic Enablers deriving from their particular use cases and provide a testing infrastructure on which the platform can be validated through large scale trials;
- infrastructure support block aims at identifying existing and future experimental infrastructures across Europe and to incorporate them in the large scale trials;
- Finally, the fourth building block facilitates coordination and support to the program.

In its first phase, FI-PPP aims at setting the requirements for the technological foundation, or the Core Platform through eight use cases in different Usage Areas, by deriving the architecture and identifying the Generic Enablers of the Core Platform; defining the Usage Area requirements on the Future Internet for supporting their business processes, and identifying the scenarios for early trials including the infrastructure to support them and starting the implementation of domain specific functionalities. Furthermore, during the first phase the program aims at starting the evaluation of test infrastructures and considering where investments need to be made to bring infrastructures to the level necessary to enable trials and establishing the program support and coordination structures.

The following Usage Area projects have received funding and were kicked-off on April 1, 2011 (see also Figure 2, more information is available on http://www.fi-ppp.eu/projects page):

- **FINEST -** Future Internet enabled optimization of transport and logistics business networks.
- **INSTANT MOBILITY** - In the Instant Mobility vision, every journey and every transport movement is part of a fully connected and self-optimizing ecosystem.
- **SMART AGRIFOOD -** Smart food and agribusiness: Future Internet for safe and healthy food from farm to fork.
- **FINSENY -** Future Internet for smart energy: foster Europe's leadership in ICT solutions for smart energy, e.g. in smart buildings and electric mobility. Coordinator: Nokia Siemens Networks

- **SafeCity -** Future Internet applied to public safety in Smart Cities: To ensure people feel safe in their surroundings.
- **OUTSMART -** Provisioning of urban/regional smart services and business models enabled by the Future Internet: water and sewage, waste management, environment and transport. Coordinator: France Telecom.
- **FI-CONTENT** - Future media Internet for large-scale content experimentation e.g. in gaming, edutainment & culture, professionally and user generated content. Coordinator: Technicolor.
- **ENVIROFI** - to leverage the Future Internet for environmental monitoring and management applications (see also below).

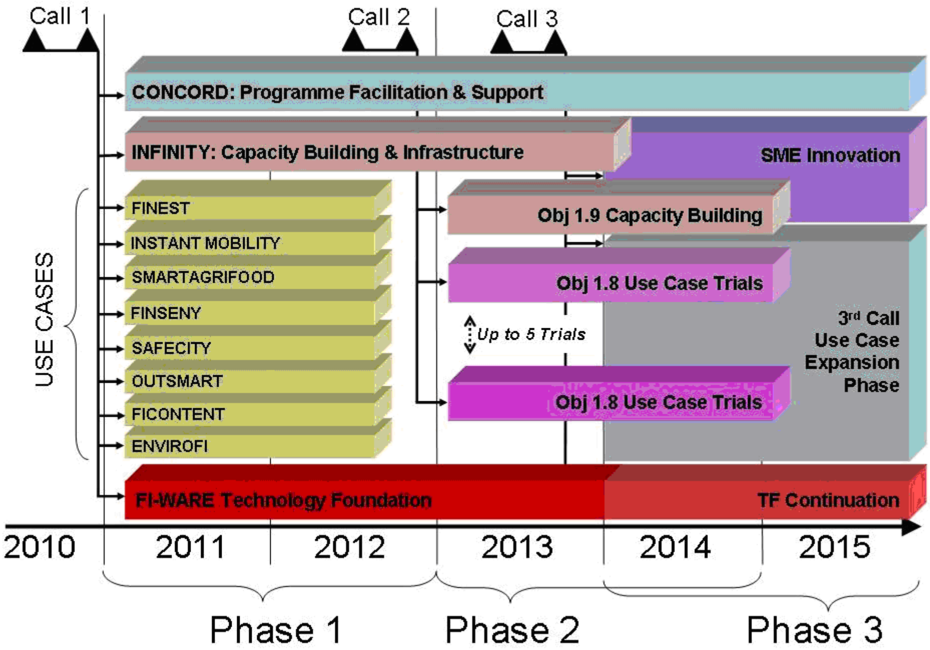

Figure 2: Overview of the FI-PPP Programme

2.2 The Need for an Environmentally Enabled Future Internet

Both the scientific and the societal necessity for environmentally enabled Future Internet have been evaluated and presented in several publications (Lemke 2010, Schade 2010, Havlik 2011, Hřebíček 2011). We briefly present the central arguments below.

2.2.1 Scientific Context

In terms of required research, the following activities should be highlighted:

- The International Council for Science (ICSU) emphasizes (i) development of observation systems needed to manage global and regional environmental change; (ii) improvement of the usefulness of forecasts of future environmental conditions and their consequences for people; and (iii) investigation of institutional, economic and behavioral responses that can enable effective steps toward global sustainability (ICSU 2011) as three of the five scientific Grand Challenges in global sustainability research.

- These three challenges perfectly correlate with the core research areas for the environmental Usage Area within Future Internet, which were identified by experts attending the workshop 'Future Sensor Web and Its Applications' in Ispra, Italy, in late January 2010 (Figure 3).

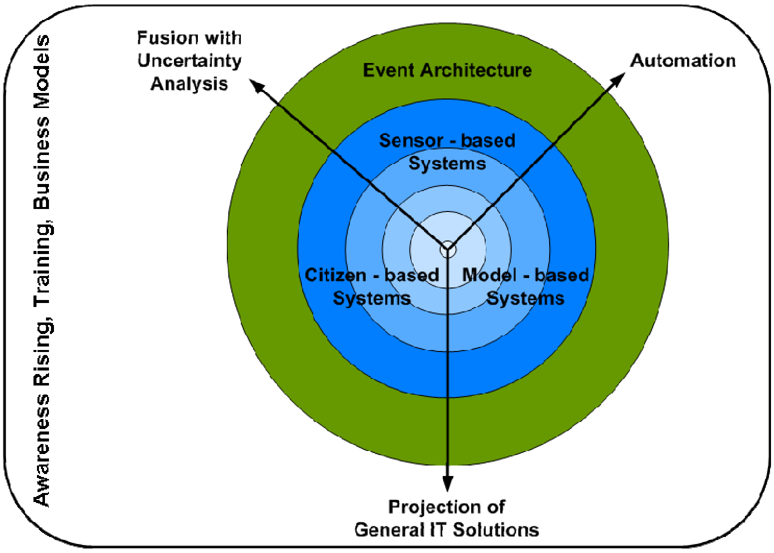

Figure 3: Main research areas for the future Sensor Web and its applications (Schade 2010, modified)

- Investigations on how the overall scientific challenges are addressed by current European-funded research projects are on-going within the Environmental Information Infrastructures and Platforms (ENVIP) community. As a general tendency, Spatial Data Infrastructures (SDI) are perceived as the new 'data silos' of the Environmental Usage Area, and the upcoming challenge is to seamlessly integrate environmental ICT and data into foreign domain and mainstream applications.

2.2.2 Political context

On the political side, the scientific challenges are complemented by:

- The concept of eEnvironment has been established as part of eDemocracy, which particularly addresses to use of Internet technology to improve citizens' participation in policy and government, and especially of eGovernment as a sub working area. The Digital Agenda for Europe, one of the seven flagship initiative of the Europe 2020 Strategy (ec.europa.eu/eu2020/), and the European eGovernment Action Plan 2011-2015 (COM(2010) 743), particularly challenge the development and deployment of cross-border eEnvironment services for the European continent.
- Both of the above are complemented by the philosophy of Open Data, which promotes free availability of data to everyone. The Open Knowledge Foundation can be seen as the most prominent advocate of the open data principle. They already put an Open Government Data Initiative into place (http://opengovernmentdata.org/). The European Commission announced recently to follow similar principles. Together with the Directive 2003/98/EC of the European Parliament and of the Council of 17 November 2003 on the re-use of public sector information (PSI Directive), this may change the landscape for the environmental ICT sectors in Europe in near future.
- Supporting the issues mentioned above for the environmental sector and again within the framework of the Digital Agenda, the European Commission set out Shared Environmental Information System (SEIS) in 2008 (http://ec.europa.eu/environment/seis/). Most interestingly SEIS considers not only classical environmental information, but also reports and policy documents.

2.3 Environmental Applications Today and Tomorrow

In order to explain the possible implications of the FI-PPP for the ICT for environment sector, this section briefly lists a few examples and issues to be considered within the Environmental Usage Area. From this we derive a value chain for disseminating environmental knowledge as (eEnvironment) services, and, furthermore, identify involved stakeholders. This section summarizes some of our previous work (Schade et al. 2011), while elaborating on some of the medium-term scenarios.

2.3.1 Expected Scenarios for the Future Internet

Given the state of art, we see three areas of major importance on land, atmospheric and marine spheres:

- The UN Convention on Biodiversity (CBD) and the EU have set a new target of halting the loss to biodiversity by the year 2020. In order to meet this goal, observational data on biodiversity must be merged from all available sources while assuring high quality. Using outreach groups for data survey, we can greatly widen the base from which observational data may be gleaned. Scenarios on biodiversity occurrence illustrate the use of humans supported by mobile devices such as smart phones as the main 'sensor' for data provision.
- Today, pollution, pollen and meteorological data which are all relatively easily accessed in one or more dissemination channels, such as television, radio and the World Wide Web. All this data contributes to a common sense, but it is not tailored to individual user needs. Relevancy of data and interpreting it are key issues for users today, especially with regards to pollen and pollution. Future eEnvironment services shall therefore aid the users towards in tailoring information relevant to their individual requirements.
- For the marine domain, the challenge for research and innovation is to create synergies with the market and with policy needs that are necessary to deliver significant value added to Europe from its vast resources. Enabling technology platforms are currently deployed across a range of existing marine related sectors including shipping, security and logistics, environmental monitoring and offshore energy. Next generation decision based management tools have to dissolve national borders. They shall address these developments in respect to distributed sensing, and wireless and cable communications.

2.3.2 Beyond 'Classical' Scenarios

As already indicated in (Havlik 2011) and (Schade 2011), FI-PPP projects, such as ENVIROFI and FI-WARE, have the potential to innovate Internet applications way beyond the scenarios that are currently foreseen within their descriptions of work. In the environmental sector for example, results may lift what is currently foreseen in the context of eEnvironment services and PSI to a new level. Beyond the cases outlined above, which are likely to become reality in the near future, we may expect applications, such as:

- A fully scalable, real-time environmental and social footprint, which provides near real-time information about individuals or groups of individuals (societies) in terms of their waste production, CO2 emission, water consumption, income, connections to other people and organizations etc. Among others, such innovation may support common efforts towards a low carbon society, as well as it may provide solutions to open issues in waste management.
- Event tracing trough observation networks, tweets and newspaper articles, in which for example natural disasters (but also political crises) are monitored from the causes, over the happening and direct responses, all the way to long term impacts, using the manifold information channels that are available. This may provide support to general safety but also on impact assessment and transparency of related (governmental) actions.

- Social networking with sensors and environmental models, which basically enables the discovery of sensor networks and event notifications, for example in case of flooding This shall lead to further convergence between the digital and the real world to the benefit (and danger) of everybody.

Given the rapid development of ICT for environment and the growing citizen interests and technological capabilities, it is likely that also such or similar applications will become reality within this decade. It is also likely that even more futuristic and unexpected applications will originate from cross Usage Area activities. Such results might contribute to the long term goals of integrated impact assessment and integrated modeling that will be required to meet the ICT-related challenges of Europe's future society.

3. Future Internet Core Platform and the Generic Enablers

As already mentioned in section 2.1, FI-WARE is the central project of the FI-PPP Programme. It is responsible for the development of the Core Platform of the Future Internet. The central business objective of the project is to strengthen the European competitiveness through provision of the infrastructure and building blocks that assure any innovative ideas can be easily turned into operative Future Internet applications.

3.1 Architectural Chapters

In its quest to develop innovative infrastructure for cost-effective creation and delivery of versatile digital services, the FI-WARE primarily targets the following main architectural 'chapters':

- **Cloud Hosting** – the fundamental layer which provides the computation, storage and network resources, upon which services are provisioned and managed.
- **Data/Context Management Services** – the facilities for effective accessing, processing, and analyzing massive streams of data, and semantically classifying them into valuable knowledge.
- **Service Delivery Framework** – the infrastructure to create, publish, manage and consume FI services across their life cycle, addressing all technical and business aspects.
- **IoT Enablement** – the bridge whereby FI services interface and leverage the ubiquity of heterogeneous, resource-constrained devices in the Internet of Things (IoT).
- **Interface to the Network and Devices** – open interfaces to networks and devices, providing the connectivity needs of services delivered across the platform.
- **Security** – the mechanisms which ensure that the delivery and usage of services is trustworthy and meets security and privacy requirements.

3.2 The FI-WARE proposition

Eight Usage Area Projects act both as early adopters and as multipliers through development of the Specific Enablers and actual applications on top of the Core Platform. The success of the FI-WARE, and indeed of the whole FI-PPP Programme is thus highly dependent on the acceptance of the Core Platform and Generic Enablers by the Usage Area projects, and requires a high level of cooperation among the projects. This necessity for cooperation reflects in following principles:

1. All FI-PPP projects are committed to coordination of the work on organizational (through program-level Steering Board), as well as on the technical level (through architectural board and ad-hoc working groups).
2. All specifications of the Core Platform architecture, Generic and Specific Enablers shall be published as 'open specifications', thus allowing all interested parties to develop their own implementations of the FI-PPP components and applications.

3. Reference implementations of the Generic Enablers shall be developed by FI-WARE and available to all FI-PPP projects free of charge.

As a consequence, every Usage Area project shall be able to install and use their own instance of the Core Platform featuring the subset of Generic Enablers required for their own applications (Figure 4). In addition, FI-WARE project shall maintain a testbed which can be used by projects that do not need the full power of and full control over a separate FI-Core Platform instance.

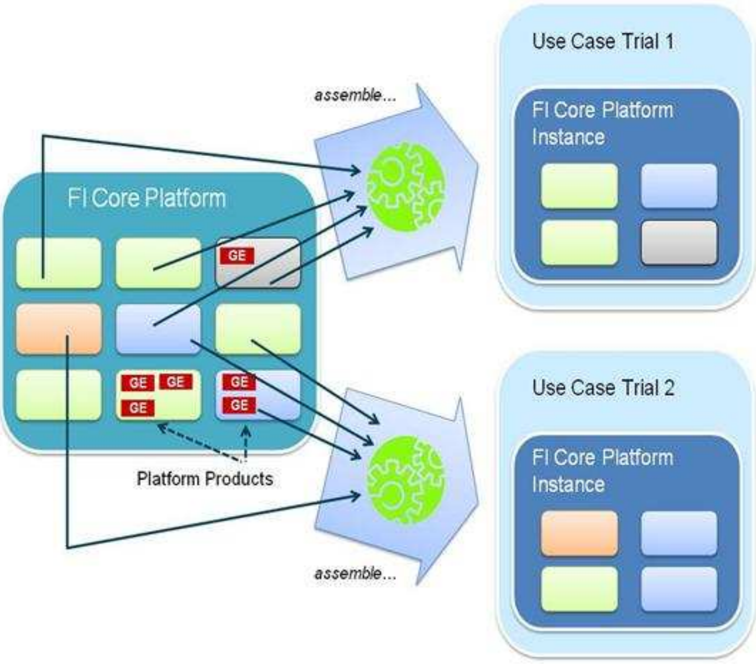

Figure 4: FI-WARE Instances (FI-WARE 2011)

4. Environmental Usage Area of the Future Internet

The thematic domain of environmental monitoring and related software applications has a long tradition in aiming at interoperable software architectures and solutions as, by its very nature, environmental problems do not obey administrative boundaries drawn by humans. Their design has undergone fundamental changes following the need to correlate environmental information and services across various thematic domains (see also section 2.3), open it up to a wider spectrum of users (from employees in environmental agencies, over politicians in ministries up to the citizen) and make more sophisticated functions directly available within an environmental information system, such as environmental simulations or geospatial processing capabilities (Usländer 2008). Finally, the application of service-oriented design principles is the currently established trend in designing interoperable environmental software systems. Hence, the following two sections describe first the experience with this approach and the results as an offer to the FI-PPP community, and then continues with the expectations of the environmental community towards a Future Internet infrastructure.

4.1 The Offer of the Environmental Usage Area

As in many other FI-PPP Usage Areas, the transition to service-oriented solutions is still ongoing in the environmental domain, too. Service-oriented architectures (SOA) (Bieberstein et al 2006) require significant changes in business process design as well as in modeling and solution development. Large-scale environmental applications result in a system-of-systems architecture that spans multiple organizational, national and technological barriers. A recent example is the world-wide initiative to create a Global Earth Observation System of Systems (GEOSS) (GEO, 2008) hat aims to integrate existing earth observation systems into a global system that can be applied to various areas of environmental science and management.

A series of reference models (RM) (Figure 5) set the conceptual foundation of distributed systems and especially SOAs, with the latest extensions towards geospatial and sensor-related SOAs worked out by the Open Geospatial Consortium (OGC), and, in parallel, reference models for SOA worked out by the Organization for the Advancement of Structured Information Standards (OASIS, 2006), later on extended towards semantically-enabled SOAs as described in (Fensel 2008).

As a core underlying principle, the International Standardization Organization (ISO) has defined a Reference Model for Open Distributed Processing (RM-ODP) (ISO/IEC 1998). The RM-ODP constitutes a way of thinking about architectural issues in terms of fundamental patterns or organizing principles, and it provides a set of guiding concepts and terminology for building distributed systems in an incremental manner. The major idea of RM-ODP is to structure the documentation of a distributed architecture according to five viewpoints (Enterprise, Information, Computational, Technology and Engineering Viewpoint).

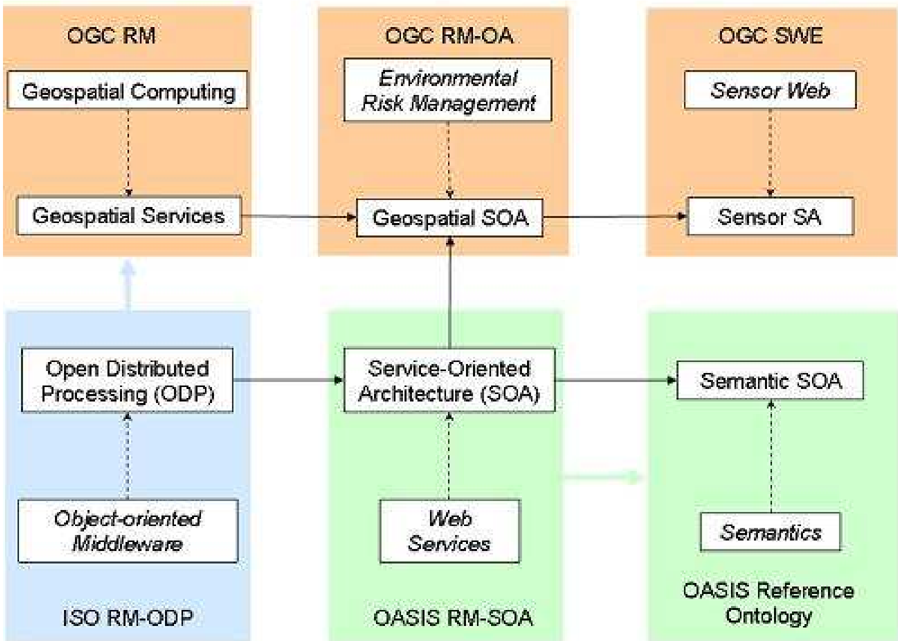

Figure 5: Evolution of Reference Models (RM) (Usländer 2009)

The European research project ORCHESTRA (Klopfer and Kannellopoulos 2008) has applied the RM-ODP approach to the specification of an Open Architecture and Spatial Data Infrastructure for Risk management. The resulting Reference Model for the ORCHESTRA Architecture (OGC 2007) interpreted the RM-ODP Computational Viewpoint as a Service Viewpoint and already distinguished in its specification between architecture services that are application-independent and may be re-used across application domains (in FI-PPP, this would correspond to Generic Enablers), and thematic-support services that are specifically tailored to support the requirements of environmental risk management applications (in FI-PPP, this would correspond to Specific Enablers). Examples of architecture services are discovery services for data and services or access services to geospatial features of all types (e.g., roads, forests or water protection areas), whereas a thematic-support service may be a profile of a geospatial processing service that performs flash flood risk assessment based upon weather and water gauge monitoring data.

The European research project SANY (Klopfer and Simonis 2009) has extended the RM-OA towards a Sensor Service Architecture (SensorSA) (OGC 2009) by the inclusion of sensors as refined geospatial features and associated access, tasking and discovery services for sensor observations. Hereby, the SensorSA relies upon the information models for observations and measurements and the corresponding service specifications of the Sensor Web Enablement (SWE) initiative as part of the OGC (OGC 2008).

These specifications offer a service platform that already contains a high percentage of the required functionality of environmental applications. Their interfaces and services have been organized in so-called functional domains as illustrated in Figure 6 and explained in the SensorSA. ENVIROFI provides the unique opportunity to feed the reference models and gained experiences into larger developments in other Usage Areas, while at the same time reviewing and possibly adapting the geospatial reference models in the light of Generic Enablers.

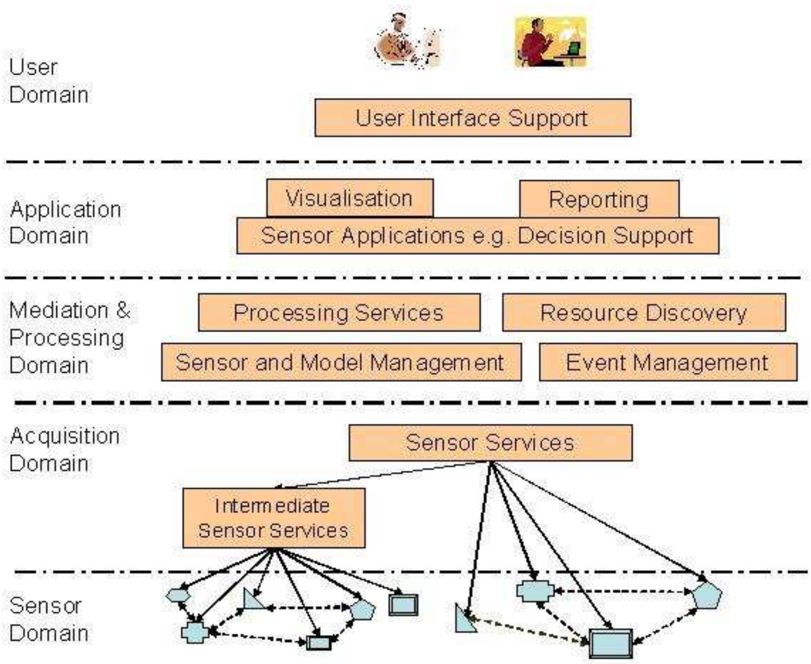

Figure 6: Functional Domains of an Open Sensor Service Architecture (OGC 2009)

5. Preliminary Conclusion

In spite of its position as one of the pillars of eDemocracy and existing pan-European and even worldwide environmental systems (of systems), several of the key issues of the Environmental Usage Area are still considered as grand (research) challenges today. The development of interoperable web-enabled environmental information systems in general, and of the standardized geospatial information systems in particular, has evolved in parallel to the Internet developments starting from the mid 90s, In spite of undeniable successes (large web-enabled systems of systems, widely accepted standards, impressive applications), the Environmental Usage Area has reached the point where further development is seriously hindered by lack of co-operation with other societal and economical potent Usage Areas:

1. The Quality of Service which can be achieved by our offerings is hindered by the capabilities of the underlying internet infrastructure.

2. The usability of our offerings is hindered by a lack of the cross- usage area interoperability.

Finally, the price and capability of Environmental Information Systems and applications are negatively affected by vendor lock resulting from the lack of standardization at the Internet of Things level, as well as from the lack of affordable and easily scalable generic processing solutions for processing the avalanche of observations available on the Web. Our preliminary analysis of the first 'FI-WARE high-level description' document (FI-WARE 2011), has identified both great opportunities to solving some of the above mentioned issues and great risks for re-inventing some of the functionality which has already been established in the Environmental Usage Area – possibly in a manner that would make the re-use of environmental resources across usage areas (and vice versa) even more difficult in the future. There will be an agile and iterative requirements analysis process across the FI-PPP projects taking into account the emerging capabilities of the Future Interne Core Platform.

In particular, The 'Cloud Hosting' plans of the FI-WARE are likely to be warmly welcomed by most stakeholders of the Environmental Usage Area:

- A layered approach to cloud hosting will allow users to choose which level of virtualization is most appropriate for their needs – from Infrastructure as a Service (IaaS), where the client rents raw resources, over Platform as a Service (PaaS), where much of the system administration is outsourced, to Software as a Service (SaaS), where complete software development, deployment and maintenance is performed by a SaaS provider.
- Standardization of the cloud services promises improved portability of the cloud-enabled applications. This will empower the users, minimize the risk of vendor lock by minimizing the effort required to move applications between various cloud offerings.
- FI-WARE promises many improvements in service management and monitoring. The two most prominent consequences of these improvements will be: (1) improved quality of service and (2) possibility to allocate storage and computing resources at users' location(s), whilst still benefiting from the advantages of the 'cloud"' virtualization technologies.

The 'Internet of Things (IoT) Enablement' chapter is also highly important for the Environmental Usage Area and thus for the ENVIROFI project. It discusses various functionalities required for interaction with Internet of Things. This chapter concentrates on web-enabling of the IoT resources roughly at the same level as OGC Sensor Web Enablement– but without clear commitment to actually embracing the OGC SWE at this level.

In summary, the FI-WARE architecture and the functionalities of the Generic Enablers will, to a large extent, be driven by requirements from Use Case projects in the context of the FI-PPP Programme. In addition, FI-WARE will welcome additional requirements brought by partners of the FI-WARE consortia (based on input of their respective business units) or gathered from third parties external to the FI-PPP projects. The window of opportunities for the stakeholders to influence the FI-PPP developments has been opened; now we have to use it.

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Literature

Bieberstein, N., Bose, S., Fiammante, M., et al. (2006). Service-Oriented Architecture (SOA) Compass – Business Value, Planning and Enterprise Roadmap. IBM Press developerWorks Series. ISBN 0-13-187002-5.

Fensel, D., Kerrigan, M. and Zaremba, M. (2008). Implementing Semantic Web Services - The SESA Framework. ISBN 978-3-540-77019-0.

FI-WARE (2011). FI-Ware high level description. Deliverable of the FI-WARE project.

GEO (2008). The Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan. Group on Earth Observation (GEO) Website. http://www.earthobservations.org.

Havlik, D., Schade, S., Sabeur, Z.A. et al. (2011). From Sensor to Observation Web with Environmental Enablers in the Future Internet. *Sensors* 11 (4).

Hřebíček, J and Pillmann, W. (2011) eEnvironment: Reality and Challenges for eEnvironment Implementation in Europe. In: Environmental Software Systems. Frameworks of eEnvironment, Proceedings of the 9th IFIP WG 5.11 International Symposium, ISESS 2011, Brno, Czech Republic.

ICSU (2011) Scientific Grand Challenges identified to address global sustainability – ISCU pre-publication, http://www.icsu-visioning.org/wp-content/uploads/GrandChallenges_Pre-publication.pdf.

ISO/IEC (1998). Information technology - Open Distributed Processing – Reference Model.

Klopfer, M. and Kannellopoulos, I. (2008). ORCHESTRA – An Open Service Architecture for Risk Management, ISBN 978-3-00-024284-7.

Klopfer, M. and Simonis, I. (2009). SANY - an open service architecture for sensor networks. ISBN 978-3-00-028571-4.

Lemke, M. (ed.) (2010). Towards a Future Internet Public - Private Partnership: Second Usage Areas Workshop Brussels, 21st-22nd June 2010, Workshop Report.

OASIS (2006). Reference Model for Service Oriented Architecture 1.0. Committee Specification 1.

OGC (2007). Reference Model for the ORCHESTRA Architecture Version 2.1. Ed.: Usländer, T., OGC Best Practices Document (07-097).

OGC (2008). OGC Sensor Web Enablement Architecture Version 0.4.0. Ed.: Simonis, I. OGC Best Practices Document (06-021r4).

OGC (2009). Specification of the Sensor Service Architecture, Version 3.0 (Rev. 3.1). OGC Discussion Paper (09-132r1).

Rizzoli, A.E., Schimak G., Donatelli M., et al. (2010). TaToo: tagging environmental resources on the web by semantic annotations. In: Proceedings of the International Congress on Environmental Modelling and Software Modelling for Environment's Sake. Ottawa, Ontario, Canada.

Schade, S., Fogarty, B., Kobernus, M., et. al. (2011). Environmental Information Systems on the Internet - A Need for Change. In: Environmental Software Systems. Frameworks of eEnvironment, Proceedings of the 9th IFIP WG 5.11 International Symposium, ISESS 2011, Brno, Czech Republic.

S. Schade (ed.) (2010). The Future Internet PPP and its Usage Areas: A Sensor Web for the Environment in Europe. Position paper for 2nd Usage Area Workshop: Future Internet Initiative.

Usländer, T. (2008). The Growing Importance of Open Service Platforms for the Design of Environmental Information Systems. In: Proceedings of iEMSs, ISBN: 978-84-7653-074-0, Vol. 3.

Usländer, T. (2009). Architectural Viewpoints and Trends for the Implementation of the Environmental Information Space. In: Proceedings of the European conference Towards eEnvironment, ISBN 978-80-210-4824-9.