SEVENTH FRAMEWORK PROGRAMME

ICT PPP

Future Internet

The Environmental Observation Web and its Service Applications within the Future Internet

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Collaborative project

D4.2 Environmental Architecture

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Glossary

The glossary of terms used in this deliverable can be found in the public document "ENVIROFI_Glossary.pdf" available at: http://www.envirofi.eu/

Abbreviations and Acronyms

Abbreviation / Acronym	Description
DAE	Digital Agenda for Europe
DEWS	Distant Early Warning System (FP6 project)
DG-INSFO	Information Society and Media Directorate General of the European Commission
EIF	European Interoperability Framework
EIS	European Interoperability Strategy
ENVISION	ENVIronmental Services Infrastructure with Ontologies (FP7 project)
EO2HEAVEN	Earth Observation and Environmental Modelling for the Mitigation of Health Risks (FP7 project)
EU	European Union
EVNS	ENVIROFI specific enabler category: Event detection and notification services
FCAT	ENVIROFI specific enabler category: Federated Catalogues
FI-PPP	Future Internet Public Private Partnership FP7 Programme
FI-WARE	Core project of the FI-PPP
FP6	Sixth Research Framework Programme of the European Union
FP7	Seventh Research Framework Programme of the European Union
FUSE	ENVIROFI specific enabler category: Fusion tools for heterogeneous data sources
GCMD	NASA's Global Change Master Directory
GE	Generic Enablers (of the FI-PPP), developed by FI-WARE
GEMET	GEneral Multilingual Environmental Thesaurus
GENESIS	GENeric European Sustainable Information Space for environment (FP7 project)
GENESIS-DR	Ground European Network for Earth Science Interoperations - Digital Repositories
GEOC	ENVIROFI specific enabler category: Geo-referenced data collection applications
GEOS	ENVIROFI specific enabler category: Geospatial data provisioning and storage
GEOSS	Global Earth Observation System of Systems
GFM	General Feature Model
GITEWS	German Indonesian Tsunami Early Warning System
GML	Geography Markup Language
HMED	ENVIROFI specific enabler category: Harvesters, connectors and mediators
HTML	Hyper Text Markup Language
I2ND	Interface to Networks and Devices
IaaS	Infrastructure as a Service

Abbreviation / Acronym	Description
ICT	Information and Communication Technology
IFCD	INSPIRE Feature Concept Dictionary
INSPIRE	Infrastructure for Spatial Information in the European Community
IoT	Internet of Things
ISO	International Organization for Standardization
JDL	Joint Directors of Laboratories
LOD	Linked Open Data
netCDF-U	Network Common Data Form – Uncertainty conventions
O&M	Observations and Measurements
OGC	Open Geospatial Consortium
OMG	Object Management Group
OPeNDAP	Open-source Project for a Network Data Access Protocol
ORCHESTRA	Open Architecture and Spatial Data Infrastructure for Risk Management (FP6 project)
OWL	Web Ontology Language
PaaS	Platform as a Service
PSI	Public Sector Information
QoS	Quality of Service
R&D	Research and development
RDF	Resource Description Framework
REST	Representational State Transfer
RM-OA	Reference Model for the ORCHESTRA Architecture
SaaS	Software as a Service
SANY	Sensors Anywhere (FP6 project)
SBA	GEOSS Societal Benefit Area
SDI	Spatial Data Infrastructure
SE	Specific Enablers (of the FI-PPP)
SensorML	Sensor Model Language
SI	Système international d'unités
(S)KOS	(Simple) Knowledge Organisation System
SLE	Service Level Agreements
SOA	Service-oriented Architecture
SOAD	Service-oriented Analysis and Design
SPARQL	SPARQL Protocol And RDF Query Language
SQL	Structured Query Language
SSNO	Semantic Sensor Networks Ontology
STAG	ENVIROFI specific enabler category: Semantic tagging tools
SWE	Sensor Web Enablement
SWEET	Semantic Web for Earth and Environmental Terminology
THREDDS	Thematic Real time Environmental Distributed Data Services

Abbreviation / Acronym	Description
TRIDEC	Collaborative, Complex and Critical Decision-Support in Evolving Crisis (FP7 project)
UML	Unified Modelling Language
UncertML	Uncertainty Markup Language
URI	Uniform Resource Identifier
VGI	Volunteered Geographic Information
XACML	Extensible Access Control Markup Language

Table 0-1. Abbreviations and Acronyms

Executive Summary

This document describes the software architecture of the European research project ENVIROFI http://www.envirofi.eu/) which is one of the eight Usage Area projects of the Future Internet Public-Private-Partnership (FI-PPP, http://www.fi-ppp.eu/). ENVIROFI deals with requirements of the environmental domain and aims at enabling the Environmental Observation Web and its Service Applications within the Future Internet.

As such the design and documentation approach of the ENVIROFI Environmental Architecture is heavily interlinked with the overall structure of the FI-PPP project cluster. In particular, it relies upon the results of the FI-WARE project that is running in parallel to ENVIROFI and the other FI-PPP use case projects. FI-WARE specifies and implements the Core Platform of the Future Internet comprising a consistent set of components, so called Generic Enablers, which shall be re-usable across all usage areas. Components developed by Usage Area projects are called “Specific Enablers”, to indicate that they may not be of use for all usage areas.

ENVIROFI focuses on environmental applications exemplified by three application pilots to be deployed in the Terrestrial, Atmospheric and Marine environments in collaboration with large stakeholder communities. They set the stage for large-scale trials in the Environmental Usage Area with a perspective of achieving sustainable socio-economic progress in Europe.

As such the ENVIROFI Environmental Architecture comprises generic, but environmental domain-specific functionality. As the environmental domain heavily relies upon geospatial data and services, environmental enablers may further be sub-classified into geospatial enablers and environmental enablers that are specific to environmental disciplines such as air quality, biodiversity, hydrology or hydrogeology.

The ENVIROFI Environmental Architecture targets the design of distributed systems or, on a higher abstraction level, the design of systems of autonomous systems loosely-coupled by means of self-description and open standardized interfaces. The specification of the ENVIROFI Environmental Architecture relies upon the following pillars:

- Reference models originally specified by standardization organizations such as ISO, OGC, OMG, OASIS and The Open Group, and tailored to the environmental domain by a series of European research projects such as ORCHESTRA, SANY and EO2HEAVEN.
- Geospatial services and information models being specified by ISO and OGC and profiled by these projects.
- Architectural styles, design patterns and (partial) solutions specified and implemented by European research projects such as ORCHESTRA, SANY, EO2HEAVEN, SWING, ENVISION, EuroGEOSS and TRIDEC.

The present document describes how these approaches are applied, combined in terms of a multi-style architecture and interpreted as “Environmental Enablers” to be mapped to the FI-PPP Core Platform. It uses the approach of the ISO Reference Model for Open Distributed Processing (ISO RM-ODP) to structure the architecture specification in terms of architectural viewpoints. Starting from the results of the requirements analysis documented in the Enterprise Viewpoint (see ENVIROFI deliverable D4.1) this document encompasses the conceptual architecture in the Information and the Computational (also called Service) Viewpoint. Furthermore, it provides guidance for the design of pilot-specific implementation architectures on top of the FI-PPP Core Platform in its descriptions of the Engineering and the Technology Viewpoints, whereby the latter hereby coincides with the characteristics and the operational issues of the FI-PPP core platform.

In addition to serving as a reference document and blueprint for environmental software architects, the conceptual elements of this document are fed back to the standardization organizations by editorship and active contribution to the ISO 19119 revision and to the Part 4: Service Centric View of the CEN/TC 287 Technical Report 15449 on Geographic information - Spatial Data Infrastructures.

1 Introduction

ENVIROFI is one of the eight Usage Area (UA) projects of the Future Internet Public-Private-Partnership (FI-PPP). Developed as a part of the recovery package after the world economic crisis, FI-PPP is an experimental research program of the Information Society and Media Directorate General of the European Commission (DG-INSFO) trying to answer the perceived deficiencies of the FP7. One of the key differences between FI-PPP and other FP7 Programmes is demand for strong co-operation among the research projects. In particular, the programme demands alignment of the IT architectures of all FI-PPP projects and design of the reusable “Future Internet Enablers”.

The central project of the FI-PPP Programme is called FI-WARE. It comprises a consortium consisting of major European Information and Communication Technology (ICT) organizations and aims at establishing the Core Platform for the Future Internet. This Core Platform features a consistent set of components, so called Generic Enablers (GE) which should be re-usable across all usage areas. Components developed by UA projects are called “Specific Enablers” (SE), to indicate that they may not be of use for all UAs.

The design and documentation approach of the ENVIROFI Environmental Architecture is heavily interlinked with the overall structure of the FI-PPP project cluster. In particular, it relies upon the results of the FI-WARE project that is running in parallel to ENVIROFI and the other FI-PPP use case projects.

Figure 1-1 illustrates the major interdependencies between the developments in the various ENVIROFI work packages (WP) and the results of FI-WARE. According to the FI-PPP Programme the kernel concept is the “enabler”. For the ENVIROFI Environmental Architecture an enabler is defined as “a software component in an implementation architecture with a well-defined interface that fulfils a given set of functional, informational and qualitative requirements”. As a result implementation architectures in FI-PPP are expressed in terms of an aggregation and collaboration of enablers.

According to their level of abstraction, enablers are organized in “platforms” that makes available re-usable functions for applications.

The left-hand side of Figure 1-1 presents this idea for the developments in ENVIROFI. The requirements stemming from the three case studies (pilots) in WP1, WP2 and WP3 have been documented in terms of scenarios and use cases. These will be implemented by WP1, WP2 and WP3 pilot applications. However, these pilot applications shall exploit as much as possible both

- <u>generic, domain-independent functionality</u>: made available by the FI Core Platform (comprising so-called generic enablers (GE) as specified and implemented by the FI-WARE project); and,
- <u>generic, but environmental domain-specific functionality</u>: made available by the ENVIROFI Platform (comprising environmental enablers as specified and implemented in ENVIROFI WP5).

Note: As the environmental domain heavily relies upon geospatial data and services, environmental enablers may further be sub-classified into geospatial enablers and environmental enablers that are specific to environmental disciplines such as air quality, biodiversity, hydrology or hydrogeology.

The right-hand side of Figure 1-1 presents the corresponding architectural approach for the platform specification and development. In ENVIROFI this work is performed in WP4 and documented in three consecutive deliverables: D4.2 (this document), D4.3 and D4.4. An agile software requirements approach has been agreed between FI-WARE and the FI-PPP use case projects. As a consequence, the design of the fitting software architecture is also performed in an agile manner. Hence, these three deliverables comprise refined and upgraded revisions of the ENVIROFI Enabler Architecture based upon the FI-WARE Architecture, accordingly. As a result, the ENVIROFI Environmental Enabler Architecture and the way it is documented is considered as a specialization, extension and refinement of the FI-WARE Architecture for the environmental domain.

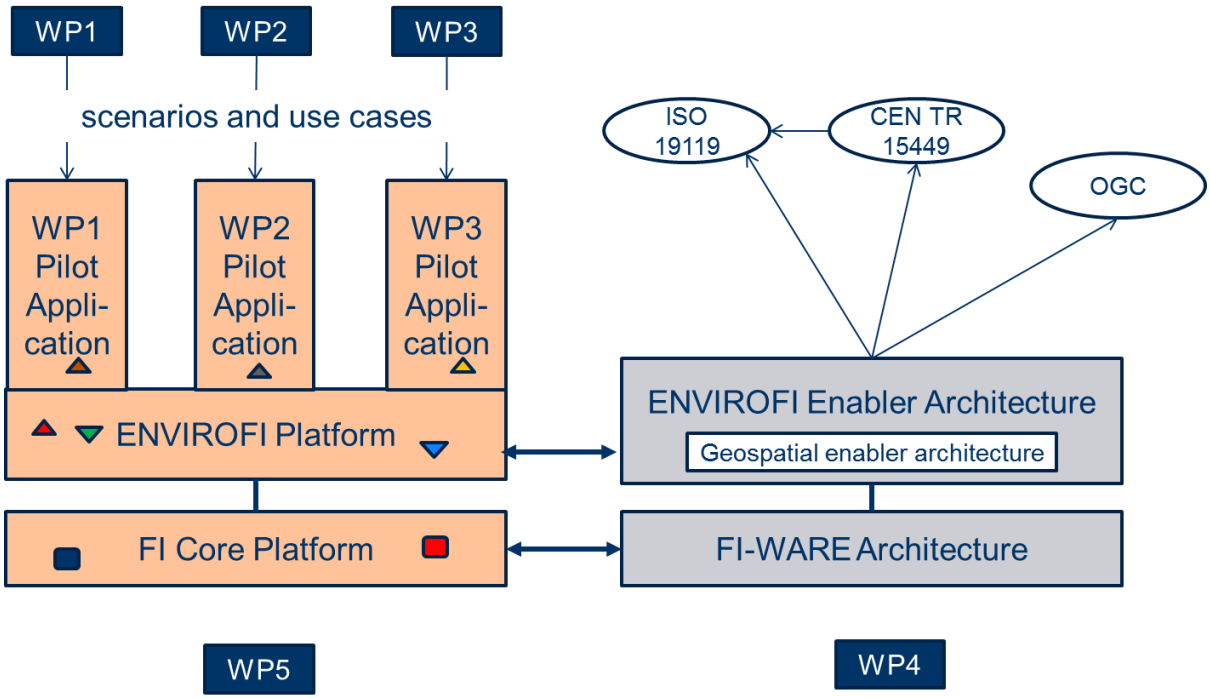

Figure 1-1. The Position of the ENVIROFI Platform and Architecture

However, as shown in Figure 1-1, ENVIROFI aims at providing an open solution based upon (geospatial) standards. Even more, it aims at influencing and contributing to current standardization work in ISO, CEN and the Open Geospatial Consortium (OGC). In particular, ENVIROFI contributes to:

- CEN Technical Report 15449: Geographic information — Spatial Data Infrastructures — Part 4 : Service Centric View[1]
- Revision of ISO 19119
- Emerging and evolving OGC standards, especially in the Sensor Web Enablement (SWE) initiative.

The ENVIROFI contributions are conveyed by means of personal engagement and editorship[2], active participation in the respective working groups[3] as well as written contributions and comments.

[1] See the draft of the CEN Technical report 15449 as confidential annex to this deliverable

[2] The ENVIROFI WP4 leader Arne Berre (SINTEF) is editor of the ISO 19119 revision and TR 15449

[3] The editors of this deliverable are also participating in the editorial group for CEN TR 15449

2 Relationship to Service-Oriented Reference Architectures

This section provides an overview about the evolution of geospatial reference architectures and their relevance for the ENVIROFI architecture. In particular, it gives a justification to apply the viewpoint approach of ISO Reference Model for Open Distributed Processing (ISO/IEC 10746-1:1998) for the documentation of the ENVIROFI architecture.

2.1 Reference Models

For many years, the European Commission has supported research activities to analyze user and system requirements, to derive architectural principles, and to specify and implement generic components of ICT architectures for large-scale environmental information systems (Coene and Gasser, 2007). In parallel, on a world-wide level, various approaches of standardization organizations such as ISO, OGC, OMG, OASIS and The Open Group were launched to stimulate a market based on agreed architectures with the aim of fostering interoperable solutions. Each standardization activity has started by the definition of terms, high-level concepts and their relationships, resulting in a series of reference models (see Figure 2-1), partly competing and partly complementary.

OASIS (2006) defines a reference model (RM) as an "abstract framework for understanding significant relationships among the entities of some environment. It enables the development of specific reference or concrete architectures using consistent standards or specifications supporting that environment." These reference models set the conceptual foundation of distributed systems. Originally inspired by the architectural style of interacting objects for distributed processing (see the ISO RM-ODP presented below in section 2.2 and illustrated in the lower left corner of Figure 2-1), they are nowadays discussed in the context of SOAs.

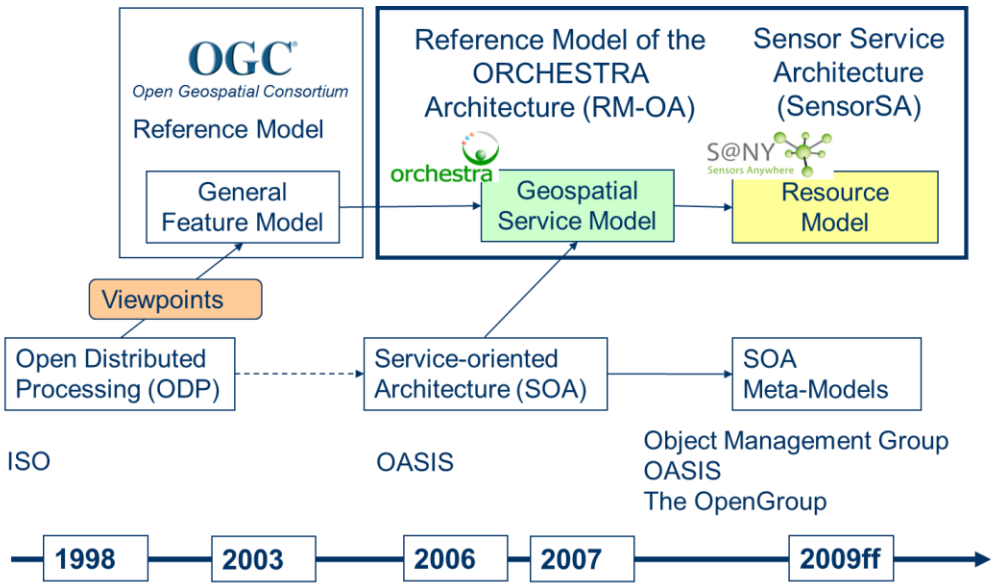

Figure 2-1. Evolution of Reference Models

Figure 2-1 illustrates the two major evolution lines of reference models. The upper line shows the interpretation of the RM-ODP for geospatial distributed processing. It has started with the OGC Reference Model (section 2.1.1) followed by the Reference Model for the ORCHESTRA Architecture (RM-OA) (Usländer, 2007) which was developed as a reference architecture for environmental risk

management as part of the ORCHESTRA project[4]. The latest extensions include sensors and sensor service networks resulting in the Sensor Service Architecture (SensorSA) (Usländer (ed.), 2009) based upon OGC Sensor Web Enablement architecture (Simonis (ed.), 2008). The RM-OA and the SensorSA were both influenced by the specification of SOA reference models that were drafted by OASIS. Their evolution is shown in the lower line in Figure 2-1.

2.1.1 OGC Reference Model

The original OGC Reference Model of 2003 (Percivall (ed.), 2003) laid the basis for the development of a series of OGC standards for geospatial services and information models. The OGC Reference Model interprets the RM-ODP viewpoints as described below in 2.2. However, it does neither provide any guidance about how to use and order the viewpoints in a design process, nor is the interpretation oriented at the principles of service-oriented computing.

As language for the specification of the information viewpoint it adopted the specification of the General Feature Model (GFM) defined in the ISO rules for application schema (ISO 19109:2005). The GFM is a meta-model for information models using UML extension mechanisms (OMG, 2007). It defines a feature as an abstraction of a real world phenomenon. A feature is the basic unit for information modelling. Individual feature instances are grouped into feature types where all instances of a certain type are described by common properties such as thematic, temporal or spatial attributes or associations with other feature types.

For the specification of the computational viewpoint the OGC Reference Model identified types and names of geospatial services and categorized them according to ISO 19119:2005 (see section 0). An overview and short introduction to all OGC standards that are derived from the OGC Reference Model (Version 0.1.3) of 2003 is covered by its latest version of 2008 (Percivall (ed.), 2008).

Hence, starting from a conceptual architectural framework in 2003 that guided a series of OGC standardization work, the OGC Reference Model now provides a kind of structured guidance through the standards developed by OGC. However, the original specification, e.g. the General Feature Model, is still valid and relevant for the ENVIROFI architecture.

2.1.2 Reference Model of the ORCHESTRA Architecture (RM-OA)

The Reference Model for the ORCHESTRA Architecture (RM-OA) provides a platform-neutral abstract specification of a geospatial service-oriented architecture that responds to the requirements of environmental risk management applications but is not exclusively tied to this application domain. It comprises generic architecture services and information models based on and extending existing OGC specifications (Usländer, 2007).

The specification of the RM-OA required a detailed consideration of the work of standardization bodies which resulted in a complex braiding (Usländer, 2010) as illustrated in Figure 5 1 and explained below.

[4] http://www.eu-orchestra.org/

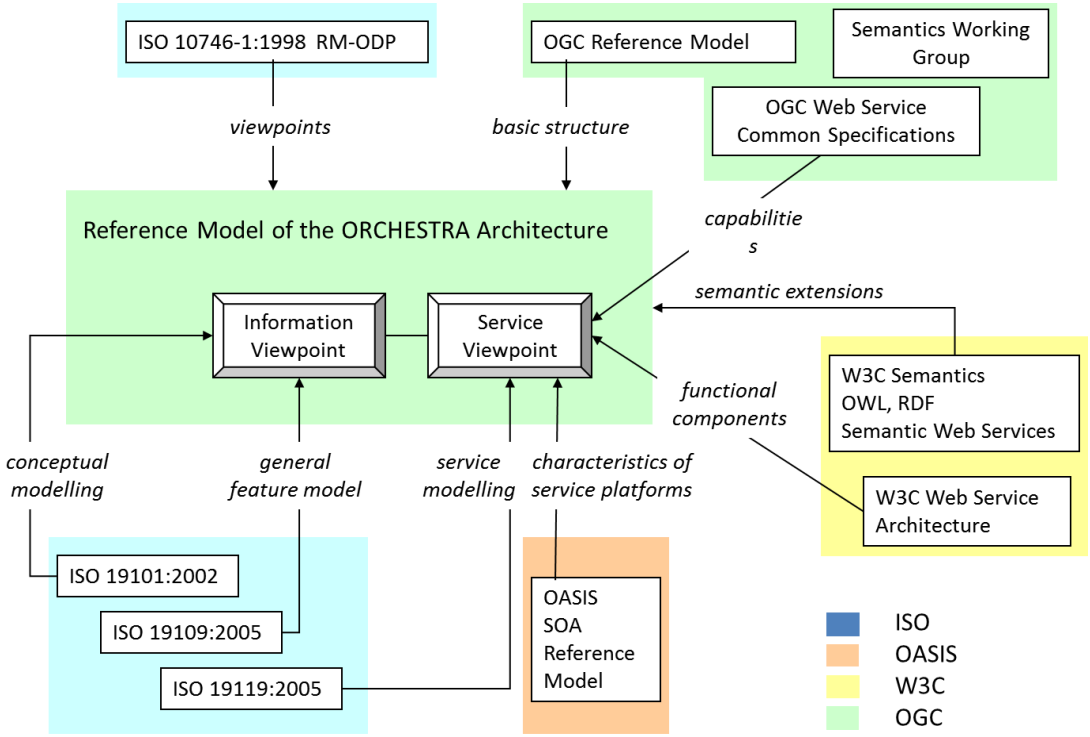

Figure 2-2. Influences of Standards to the Specification of the RM-OA

The following ISO and OGC standards heavily influenced the specification of the RM-OA models:

- The ISO/IEC 10746 Reference Model for Open Distributed Processing (RM-ODP) provided the structuring into viewpoints (as explained above).
- The OGC Reference Model (see 2.1.1) influenced the basic structure of the RM-OA document and the usage of the pertinent ISO standards.
- The conceptual modelling of the RM-OA Information Viewpoint was performed according to the basic concepts (such as a “feature”) of ISO 19101:2004 Geographic information - Reference model.
- The meta-model for information is an evolution of the General Feature Model as defined in ISO 19109:2005 Geographic information - Rules for application schema.
- The meta-model for services defined in the RM-OA Service Viewpoint is derived from ISO 19119:2005 Geographic Information - Services but harmonized with the meta-model for information (ISO 19109:2005) as described below in section 0.
- The OpenGIS® Web Service Common Implementation Specification (OGC, 2005) details many of the aspects that are, or will be (because harmonization efforts are under way), common to all OGC Web Service interface Implementation Specifications. This idea was adopted for the specification of common service characteristics in terms of reusable interfaces, for example, for the specification of their capabilities.

In 2007 the RM-OA was accepted as a best-practices architectural framework for geospatial applications by the OGC Technical Committee (OGC document 07-097, Usländer (2007)). Due to its generic and standards-based approach the author proposes it as foundation for system-of-systems engineering projects in the environmental science application domain. One example of RM-OA usage is the design and development of e-Science and technology infrastructures for biodiversity data and observatories in the LifeWatch project (Giddy et al, 2009).

2.1.3 Sensor Service Architecture (SensorSA)

The RM-OA was refined and extended towards a Sensor Service Architecture (SensorSA) (OGC discussion paper 09-132, Usländer (ed.), 2009) in the course of the European Integrated Project SANY[5] (Klopfer and Simonis, (eds.) 2009). In addition to the RM-OA, the SensorSA includes the access to sensor observations (e.g. measurement values) and the management of sensors and sensor service networks. Sensors provide the input data for environmental monitoring as well as for risk management of natural, technical and man-made hazards. The SensorSA is based upon the services and information models of the OGC Sensor Web Enablement architecture (Simonis (ed.), 2008) but puts them into the context of the RM-ODP viewpoints.

The objective of the SensorSA is to motivate and specify the basic design decisions derived from user requirements and generic architectural principles. Its focus is on a platform-neutral specification, i.e. it provides the basic concepts and their interrelationships (conceptual models) and abstract specifications.

Its relevance for ENVIROFI is derived from the fact that the SensorSA is based upon the OGC Sensor Web Enablement architecture and introduced the notion of a multi-style architecture into the geospatial domain. The SensorSA supports, in addition to the classical architectural style, which is oriented towards remote invocations, an event-driven and a resource-oriented architectural style.

As such, it foresees mechanisms to generate events and distribute them as notifications to interested consumers. This enables spontaneous distribution of information about changing configurations in underlying sensor networks, e.g. the dynamic addition or removal of sensor devices, which is a pre-requisite for the support of the “plug-and-measure” type of operation.

Furthermore, the SensorSA embeds a resource-oriented architectural style. Resource-orientation in the SensorSA refers to unique identification of geospatial resources (e.g. time series of observation results, spatial data sets) and their representations as tables, maps or diagrams. This approach provides more flexibility in the design of an implementation architecture. For instance, it enables the mapping to and the co-existence with so-called RESTful web service environments (Richardson and Ruby, 2007). By this multi-style approach, it remains a design decision of the system engineer in the engineering step which architectural style best suits the individual purpose and requirements.

2.1.4 EO2HEAVEN Spatial Information Infrastructure

The Spatial Information Infrastructure of the European research project EO2HEAVEN continues the series of architecture specifications of the previous FP6 European projects ORCHESTRA and SANY as described above. EO2HEAVEN (Earth Observation and Environmental Modelling for the Mitigation of Health Risks) contributes to a better understanding of the complex relationships between environmental changes and their impact on human health.

The EO2HEAVEN spatial information infrastructure (Kunz and Usländer (eds.), 2011) provides further extensions and refinements to the SensorSA of SANY, e.g. taking into account the requirements to share and process huge amounts of datasets provided by Earth observation agencies and health institutions in order to investigate and assess correlated risks. Furthermore, in its Engineering Viewpoint it discusses how to handle security and uncertainty issues for large datasets and discusses the aspects of moving code versus the transfer of large data sets for geospatial processing chains. These aspects will have to be reconsidered when using the FI Core platform.

Apart from these functional and informational enhancements the EO2HEAVEN spatial information infrastructure is interesting for ENVIROFI for its iterative approach in refining and upgrading the architectural specification according to emerging technologies and updates of international standards (ISO, OGC). It is envisaged to finally submit (at least parts of) the final EO2HEAVEN Implementation

[5] http://www.sany-ip.eu/

Architecture specification to OGC as an update of the OGC discussion paper SensorSA (OGC 09-132r1) incorporating the latest technological evolution as well as specifics of Earth observation and environmental modelling, hence the specific add-ons provided by the EO2HEAVEN project.

2.1.5 EuroGEOSS Architecture

The EuroGEOSS[6] multidisciplinary interoperability infrastructure builds on the three Operating Capacities of Forestry, Biodiversity, and Drought. Multidisciplinary interoperability is provided by the EuroGOSS Brokering Platform. This was developed according the Brokering Approach, which applies several of the principles/requirements that characterize the System of Systems (SoS) approach and the Internet of Services (IoS) philosophy:

1. To keep the existing capacities as autonomous as possible by interconnecting and mediating between standard-based and non-standard-based capacities.
2. To supplement, without supplanting, the individual systems' mandates and governance arrangements.
3. To assure a low entry barrier for both the resource providers and the end users.
4. To be flexible enough so as to accommodate the existing systems as well as future ones.
5. To build in an incremental fashion upon the existing infrastructures (information systems) and incorporate heterogeneous resources by introducing distribution and mediation functionalities.
6. To specify interoperability arrangements focusing on the modularity of interdisciplinary concepts rather than just on the technical interoperability of systems.

The key features of the EuroGEOSS multidisciplinary approach are the brokering and mediation capabilities that allow for discovering and accessing autonomous and heterogeneous resources from the three thematic domains of the project.

2.1.5.1 The Brokering Approach

The brokering approach extends the traditional Service Oriented Architecture (SOA) archetype by introducing "expert" components: the Brokers. These provide the necessary mediation and distribution functionalities to (i) allow service consumers to bind to heterogeneous service providers in a transparent way and (ii) interact with them using a single and well-known endpoint. Such a solution addresses some of the short-comings characterizing state-of-the-art SOA implementations, such as the lack of semantic interoperability and proliferation of standards, which jeopardize the development of complex, large, and heterogeneous infrastructures like GEOSS.

2.1.5.2 The EuroGEOSS Brokers

The EuroGEOSS Discovery Broker is central to multi-disciplinarity because it allows the EuroGEOSS framework to read and mediate between the diverse standards and specifications that are used by the distinct scientific communities. By building bridges between the practices of these communities, the EDB makes it possible to find all the datasets and services of the partners in the three thematic areas, including multiple catalogue services. By registering the EDB as a GEOSS component, all the project's thematic resources are also made accessible to the global research community.

The EDB provides harmonized discovery functionalities by mediating and distributing user queries against the multitude of services currently registered in the EuroGEOSS capability. In turn, many of

[6] http://www.eurogeoss.eu

these are catalogues or inventory services that propagate further the queries to many other resources. A key feature of the EDB is that it makes it possible to integrate widely acknowledged SOA discovery interfaces with emerging Web 2.0 resources and to easily utilize them. This list of supported formats comprises:

- Service interfaces that comply with INSPIRE and/or OGC standards.
- Service interfaces which are specific to the three thematic areas.
- Service interfaces which are widely acknowledged by other user communities, such as the Thematic Realtime Environmental Distributed Data Services (THREDDS) and the Open-source Project for a Network Data Access Protocol (OPeNDAP).
- Service interfaces defined by specific projects, such as the Ground European Network for Earth Science Interoperations - Digital Repositories (GENESIS-DR) and SeaDataNet.

Bridging between these different communities makes it possible to meet the multidisciplinary needs of scientific research without assuming that everyone will converge on one selected standard. Recently, the project set up a web portal providing access to the EuroGEOSS discovery broker.

To enhance further multidisciplinary interoperability, EuroGEOSS prototyped, in collaboration with the GENESIS FP7 project[7] and furthering the original Semantic Catalogue approach of ORCHESTRA and SANY (Hilbring and Usländer, 2008), the semantics-aware Discovery Augmentation Component which extends the capabilities of the EuroGEOSS Discovery Broker. This component implements a “third-party discovery augmentation approach” enhancing the discovery capabilities of the infrastructures that are brokered by overlaying advanced multilingual and query expansion functionalities. The Discovery Augmentation Component achieves this by issuing to existing discovery facilities (e.g. catalogues and discovery brokers) queries that have been expanded through semantic services (e.g. controlled vocabularies, ontologies, and gazetteers) by including related terms as well as translations into multiple languages. The query capabilities contribute to bridging the gap constituted by semantic heterogeneity and multilingualism, which is essential to building interdisciplinary SOA infrastructures.

Currently, two different augmented discovery styles are supported:

1. automatic query expansion, and
2. user-assisted query expansion.

With the former, the user just selects which “axis” shall be followed for expanding the query (e.g. more general terms, more specific ones, etc.). With the latter, the user can actually browse the graph induced by the terms in the thesauri (together with the relations they define) and select the terms that s/he deems pertinent to the search. In both cases, the set of terms that are identified are further expanded with multiple translations of the terms in other languages.

The geospatial thesauri that are accessed by the Discovery Augmentation Component are provided by the GENESIS Vocabulary Service as RDF data complying with the Simple Knowledge Organization System (SKOS) format and made available as a SPARQL endpoint. More importantly, the repository is also hosting the relations linking many among these thesauri. It is because of these relations that the DAC can efficiently bridge between the different thematic and application domains.

The selection and harmonization of the thesauri accessed by the Discovery Augmentation Component play an important role in enabling multidisciplinary access to resources. As an example, the GENESIS Vocabulary Service is featuring, among the other thesauri, the thematic vocabulary on drought developed by EuroGEOSS. Thus, terms from this vocabulary can be found in the metadata of resources related to this thematic area. However, users from other thematic areas, as well as the layman, may find it difficult to discover these resources because of terminology mismatch, that is, the terms they employ for a search may be different from those contained in the metadata. To address this

[7] http://www.genesis-fp7.eu/

common problem, and enable access by a wider audience, terms from the drought vocabulary have been related to some widely acknowledged terminology, such as GEMET and the INSPIRE Themes. As a result, query expansion takes care of crossing the thematic boundary and allows users to discover resources by using terms with which they are familiar that are more general than those provided by the domain specialist.

More interestingly, the query-expansion paradigm may enable multidisciplinary access to resources by coupling terminologies from different application domains. As an example, GEOSS resources may be annotated according to the Earth Observation (EO) Vocabulary, a selection of 142 “critical observation parameters” that are categorized in a three-level hierarchy according to 80 Global Change Master Directory topics and terms. On the other hand, discovery of GEOSS resources is likely to respond to a policy-making need in one of the Societal Benefit Areas (SBAs) defined by GEOSS. Therefore, terms from the EO Vocabulary have been related to the corresponding SBAs so that they can be retrieved by non-scientific users, such as decision makers.

The relations that were created among distinct thesauri represent also an example of knowledge that is generated by interdisciplinary and trans-disciplinary research. In this case, the emergence of a common goal (supporting decision making in the SBAs) and the need for access to data across thematic and application domains.

After addressing the components needed to support multidisciplinary search and discovery of information resources, the next step is to facilitate multi-disciplinary data access. By applying the same principles and technologies, the EuroGEOSS Access Broker has been developed for this purpose. It enables users to access and use the datasets resulting from their queries according to a common grid environment they have configured by selecting the following common features: Coordinate Reference System, spatial resolution, spatial extent (e.g. subset), and data encoding format. This feature is crucial to allowing effective integration and analysis of data coming from heterogeneous sources. In normal practice, the manipulation to the data necessary ahead of the analysis has to be done by the user. The EuroGEOSS Access Broker takes this burden away from the user as a true value-added service.

In keeping with the system-of-systems principles, the EuroGEOSS Access Broker carries out this task by supplementing, but not supplanting, the access services providing the datasets requested. This is achieved by brokering the necessary transformation requests, i.e., those that the access services are not able to accomplish, to external processing services. Following the principles of the Internet of Services and the Web 2.0, the EuroGEOSS Access Broker publishes Web applications allowing users to:

1. select a default business logic (i.e. algorithms) implementing dedicated processing like CRS transformation and space resolution resampling;
2. upload their own business logic (i.e. processing schemes) and set it as default;
3. select the order of the processing steps.

The EuroGEOSS Access Broker also publishes an interface which realizes the INSPIRE transformation service abstract specification.

2.1.6 TRIDEC knowledge-based data fusion framework

The knowledge-based data fusion framework of the European research project TRIDEC continues the series of architecture specifications of the previous FP6 European projects SANY as described above. TRIDEC (Wächter et al, 2011) focussed on the challenges of handling very large scale real-time data from heterogeneous sources such as sensor networks and Web 2.0 sites.

The TRIDEC knowledge-based data fusion framework is interesting to ENVIROFI since it adds both scalability and real-time processing capabilities to the SANY fusion and modelling architecture (Middleton (ed.), 2010). This information model in particular is relevant in ENVIROFI as it represents both sensor and Web 2.0 information using a combination of OGC and W3C standards. Originally inspired by the Joint Directors of Laboratories (JDL) (Lampert, 2009) information model it is designed to

support real-time access to data and results, semantic annotation of results at different levels of data fusion and re-use of results in multi-level fusion via OGC and W3C access protocols.

2.1.7 ENVISION Platform

The main objective of the ENVISION project8 is to provide an ENVIronmental Services Infrastructure with ONtologies for semantically enhanced multilingual discovery and adaptive composition of environmental services for users without ICT skills.

The ENVISION platform is based on a set of generic enablers that are fully Web-based and that interoperate in an extendable platform where other enablers can be added. The ENVISION provided enablers include:

- Semantic annotation. Services can be annotated and linked to ontology concepts with the semantic annotation enabler.
- Discovery. The discovery enabler allows finding existing services in a precise manner by exploiting the knowledge given by semantic annotated services.
- Composition. A composition enabler allows composing existing services into new composite services based on the graphical end-user friendly Business Process Modeling Notation language (BPMN).[9]
- Portal creation: Support for the creation of decision support portals, with visualisation of the results from discovered and composed resources and services.
- Mediation. A mediation enabler assists a user to semi-automatically define mappings between the data objects of services in a composition. It is based on a reasoning framework to propose initial mappings that can be refined or adjusted by the user.
- Execution. Newly created service compositions can be deployed and executed by the execution enabler. There is an automated transition from the composition enabler to the execution enabler in the ENVISION platform.

Most of the ENVISION platform enablers have a generic nature. In addition there are specific OGC specializations to provide tailored support for OGC-based services as well as general WSDL-based10 services.

[8] http://www.envision-project.eu/

[9] BPMI.org, Business Process Modeling Notation (BPMN) Version 1.0., Available at: http://www.bpmn.org/ , May 2004

[10] W3C. Web Services Description Language (WSDL), Version 2.0 Part 1: Core Language. Available at: http://www.w3.org/TR/wsdl20, August 2004

2.2 Architectural Viewpoints

An approach based on the ISO Reference Model for Open Distributed Processing (ISO/IEC 10746-1:1998) is selected for the design of the ENVIROFI Environmental Architecture. Since the ENVIROFI Environmental Architecture has the characteristic of a loosely-coupled network of systems and services instead of a “distributed processing system based on interacting objects” as presumed by RM-ODP, the RM-ODP concepts are not literally followed. The RM-ODP is used for the design and documentation of the ENVIROFI Environmental Architecture.

It is applied on a big scale to the structuring of ideas and the documentation of the ENVIROFI Architecture itself. A mapping of RM-ODP viewpoints to the needs of the ENVIROFI Environmental Architecture has been carried out and is summarised in Table 2-1:

- The first column of Table 2-1 denotes the name of the architectural viewpoint.
- The second provides the original definition according to the ISO/IEC 10746 RM-ODP document.
- The third column provides the definitions of the viewpoints as proposed by the OpenGIS Reference Model (see section 2.1.1 below) using the terms of the OpenGIS glossary.
- The fourth column presents the mapping of the RM-ODP viewpoints to the design of the ENVIROFI Environmental Architecture, i.e. the interpretation in the context of the FI-PPP project and architectural framework. In particular, it is highlighted that the technological environment of ENVIROFI applications will be pre-determined by the characteristics and the operational issues of the FI-WARE core platform, and that there is an engineering activity to map the ENVIROFI environmental enablers to such an environment. An example is the implementation of a standard OGC service (e.g. the OGC Sensor Observation Service) on top of an FI-WARE cloud-oriented data storage service.

View-point Name	Definition according to ISO/IEC 10746	Definition according to the OpenGIS Reference Model (Percivall -ed.-, 2003)	Mapping to the design of the ENVIROFI Environmental Architecture
Enterprise	Concerned with the purpose, scope and policies governing the activities of the specified system within the organization of which it is a part.	Focuses on the purpose, scope and policies for that system.	Reflects the policy context as well as the analysis phase in terms of the system and the user requirements as well as the technology assessment. Includes rules that govern actors and groups of actors, and their roles.
Information	Concerned with the kinds of information handled by the system and constraints on the use and interpretation of that information.	Focuses on the semantics of information and information processing.	Specifies the modelling approach of all categories of information the ENVIROFI Environmental Architecture deals with including their thematic, spatial, and temporal characteristics as well as their meta-information.
Computatonal	Concerned with the functional decomposition of the system into a set of objects that interact at interfaces – enabling system distribution.	Captures component and interface details without regard to distribution.	Specifies the Interface and Service Types that aim at improving the syntactic and semantic interoperability between services, source systems and applications. Note: In SOA environments, also referred to as the “Service Viewpoint” (Usländer (ed.) (2007).
Technology	Concerned with the choice of technology to support system distribution.	Focuses on the choice of technology.	Specifies the characteristics and the operational issues of the FI-WARE core platform.
Engineering	Concerned with the infrastructure required to support system distribution.	Focuses on the mechanisms and functions required to support distributed interaction between objects in the system.	Specifies the mapping of the ENVIROFI specific enablers to the FI-WARE core platform.

Table 2-1. Mapping of the RM-ODP Viewpoints to the ENVIROFI Architecture

2.3 FI-WARE Architecture

This section of the D4.2 Environmental Architecture presents the key features of the FI-WARE architecture and discusses their relevance for ENVIROFI.

2.3.1 FI-WARE Documentation and Architectural Approach

In 2011, the FI-WARE has issued three documents illustrating various aspects of the project:

1. "Overall_FI-WARE_Vision": explained the project's background, motivation and goals;
2. "FI-WARE Product Vision": provides initial architectural ideas of the FI-WARE; and
3. "Materializing the FI-WARE Vision": an overview of the existing products and standards relevant to FI-WARE work.

Finally, the preliminary version of the "FI-WARE Architecture" was made available in March 2012. In line with the overall agile development approach, all four documents can be seen as consecutive improvements of the FI-WARE ideas.

FI-WARE Architecture will be structured along six architectural "chapters", allowing:

1. Cloud Hosting: Deployment of the Future Internet services on the cloud, i.e. using cloud computing technologies.
2. Data/Context Management Services: Accessing, processing and analyzing massive data streams, as well as semantically classifying them into valuable knowledge.
3. Applications and Services Ecosystem and Delivery Framework: Creation, publishing, managing and consuming the Future Internet services.
4. IoT Services Enablement: Leveraging the ubiquity of heterogeneous, resource-constrained devices in the Internet of Things (IoT).
5. Interface to the Network and Devices (I2ND): Accessing the networks and devices through consistent service interfaces.
6. Security: Providing appropriate security mechanisms for all the above.

Each of the six chapters has been described in terms of the functional building blocks, i.e., generic enablers (GE), inter- and intra- chapter connections between these GEs and to some level in terms of the standards and preferred technologies. Unfortunately, the final version of the FI-WARE Architecture document has been delayed, and will not be made available in time for inclusion in this document.

This, and the fact that the FI-WARE (so-far) does not structure its architectural documents in architectural "viewpoints", makes the task of aligning the ENVIROFI and FI-WARE Architectures quite difficult at the current stage. The following sections provide our current understanding of the FI-WARE architectural principles, their relevant standards and technologies, and finally outline their relevance for ENVIROFI.

2.3.2 FI-WARE Architectural Principles

Combining the bits and pieces of information from the documents mentioned in the previous section as well as the information gathered on FI-PPP Architectural board Meetings, we came to following conclusions:

1. The FI-WARE Architectural chapters are highly independent from each other, and may heavily differ in terms of the standards, technologies, data models, data representations and interaction patterns.
   - "Cloud Hosting", "Applications and Services Ecosystem and Delivery Framework", "Data/Context Management Services", "I2ND" and "Security" chapters appear to be functionally independent and complementary to each other, with the exception of the "cloud edge"/"cloud proxy" enabler.
   - IoT enablement chapter overlaps with both I2ND and "Data/Context Management Services".
2. The silver lining which links the GEs of the various chapters lies in the possibility to invoke their functionality over the Internet. In addition, the FI-WARE documentation clearly indicates which of the GEs from one chapter need to be invoked by GEs of another chapter, albeit without going into details on how this will be performed.
   - It is currently unclear which type of service interfaces will be used for this invocation. Various FI-WARE documents and the user stories provided by eight UA projects mention RESTful services, SOAP and open linked data, and the discussion within the FI-PPP architectural board revealed the need for faster services which do not rely (only) on XML for data encoding.
   - Consequently, the FI-WARE architecture needs to allow co-existence of various Web service technologies. "Common Base Technologies" section of the "Materializing the FI-WARE vision" document[11] as well as the "Applications and Services Ecosystem and Delivery Framework" chapter of the FI-WARE architecture draft[12] indicate the FI-WARE preference to solve the related interoperability issues through introduction of the "middleware" or "mediator services".
3. FI-WARE documents also indicate the need for co-existence of (at least) the resource-oriented (e.g. in IoT Service Enablement chapter), request/reply and event driven architectural styles (e.g. in Data/Context management). Discussion within the FI-PPP Architectural board further-more emphasized the need for GEs supporting a stream-oriented architectural style.
   - Consequently, the FI-WARE architecture will need to accommodate several co-existing architectural styles, in-line with the ENVIROFI "multi-style architecture" approach.
4. GEs of the Data/Context management chapter are presumed to be application and UA agnostic to the level where none of the semantics that is implicitly available in OGC SWE will be a-priori known to the FI-WARE GEs. Consequently, this chapter defines the Data, Context, Event and Event Object concepts in extremely generic way.
   - It is interesting to note that the data a-priori does not carry implicit semantics and the meta-data element is *optional* according to FI-WARE architecture draft.

Disclaimer: The "principles" listed above are provided in the hope they will simplify the dialog between FI-WARE and ENVIROFI, and eventually lead to full alignment of the respective architectures. They have never been presented in this way by FI-WARE and merely represent *our current understanding of the FI-WARE ideas based on available documentation and FI-PPP Architecture Board discussions*.

[11] https://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/Common_base_technologies

[12] https://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/Architecture_of_Applications_and_Services_Ecosystem_and_Delivery_Framework_(PRELIMINARY)

3 Enterprise Viewpoint

According to Table 2-1 the Enterprise Viewpoint reflects the policy context as well as the analysis phase in terms of the system and the user requirements. This section is restricted to the first topic, i.e. the policy context. The second topic, the results of the requirements analysis, is documented in the ENVIROFI deliverable D4.1 which presents

1. the agile service-oriented analysis and design methodology being used in ENVIROFI, and
2. the resulting documentation in terms of semi-structured use case descriptions including UML diagrams for the major information resources.

Following the agile approach, this deliverable is being refined and extended according to a milestone plan. The progress is documented and maintained by Web-based tool accessible for authorized users at http://envirofi.server.de . At defined milestones, a requirements analysis document is automatically generated[13].

The aim of this section is to provide a better understanding of the issues related to semantic interoperability in the context of environmental data management in the European Union, and of measures and activities that are addressing these problems. It does so by sketching developments in information sharing and the associated EU policy context.

3.1 Information Sharing

Much of what occurs in the environmental and geospatial communities has a direct relation with the general developments in the domain of information and communication technology (ICT). Many communities of practice are embracing distributed databases and Web Services along with open standards in order to share efficiently information across the Internet (Perego, 2012). In addition, more and more information is being re-used outside the context for which it was originally created. Data and information are made accessible to a much broader community than by using traditional data distribution methods, which again leads to the adoption of new business practices. The sharing of resources across multiple information communities, each with its own natural and thematic language and cultural and historic background, poses interesting challenges on the endeavour of information infrastructures. Sufficient documentation on the intended interpretation of data—the semantics, including the relationships between concepts—becomes critical for a proper re-use of the available raw data sets and derived information.

Also the policy landscape is changing. Calls for more transparency and for boosting innovation are pushing governments to open up their data assets, often in the context of their e-Government programmes. At EU level, a common approach to these developments is further stimulated by EU legislation, common strategies, frameworks, and other policy instruments—both for ICT (European Commission, 2010a, 2010b, 2010c) and for the management of environmental information (European Commission, 2007, 2008).

3.2 European Union Policy Context

Harmonisation and interoperability of environmental data in the EU has to be seen in the context of several European policies in the areas of e-government and data sharing and management.

The Digital Agenda for Europe (DAE) (European Commission, 2010a) is one of the seven flagship initiatives of the Europe 2020 Strategy. It sets a general policy framework and defines a list of concrete

[13] Find the latest public version D4.1.1 at http://www.envirofi.eu/Portals/89/Docs/Project/Public_deliverables/ENVIROFI%20D4.1.1_Environmental_Requirements_I.pdf

actions, seven of which focus specifically on interoperability and standards. This includes activities on the promotion of open standards, common frameworks, and common services and tools. Of particular relevance in this context are the European Interoperability Strategy (EIS) (European Commission, 2010b) and the European Interoperability Framework (EIF) (European Commission, 2010c). According to the EIF, several kinds of interoperability should be considered when discussing interplay of information systems: Legal, Organisational, Semantic and Technical interoperability.

The European eGovernment Action Plan 2011-2015 advocates the development and deployment of cross-border eEnvironment services for Europe.

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. The European Commission announced recently to follow similar principles. Together with the Directive on the re-use of public sector information (PSI Directive) (European Commission, 2003), this is changing the landscape for the environmental ICT sector in Europe.

In this context, the INSPIRE Directive (European Commission, 2007) aims at establishing an infrastructure for spatial information in Europe for the purposes of EU environmental policies and policies or activities which may have an impact on the environment. INSPIRE is addressing several aspects, in particular: metadata, interoperability of spatial data sets and services, network services and data and service sharing. The spatial information considered under the directive is extensive and includes a great variety of spatial data themes. Thus, INSPIRE can be regarded as the largest semantic interoperability effort ever in the environmental domain, involving over 700 organizations worldwide. At the same time, as a multi-purpose infrastructure for the exchange and sharing of spatial data, INSPIRE could be extended to other, non-environmental, thematic sectors.

INSPIRE, as well as relevant projects that are running under the seventh Framework Programme for Research, are formal contributions of the European Union to the Global Earth Observation System of Systems (GEOSS). In fact, the achievements that Europe has reached with INSPIRE, in particular in the area of semantic interoperability, is being considered also outside the EU borders (Smits, 2011).

4 Information Viewpoint

4.1 Overview

The Information Viewpoint in the ENVIROFI Environmental Architecture specifies the modelling approach of all categories of information the generic and specific enablers deal with, including their thematic, spatial, and temporal characteristics as well as their meta-information. Modelling approach hereby means:

1. It shall be determined how data and service models are specified, i.e., the information viewpoint defines conceptual models which provide guidelines and constraints how to define data and service models.
2. There are basic data models to be applied for given purposes. These have to follow the guidelines and constraints of the conceptual models.

On this foundation, the ENVIROFI Information Viewpoint describes approaches to enable semantic interoperability (section 4.4) and presents ideas how to encompass the approach of “Linked Open Data” (section 4.5).

4.2 Conceptual Models

The conceptual model of ENVIROFI relies upon two basic pillars that have their own origin and have to be aligned in the future:

1. Data and service modeling in the geospatial domain relies upon the series of ISO/OGC geospatial standards and best-practices.
2. Domain-independent modeling relies upon the guidelines and constraints of the FI-WARE architecture draft.

4.2.1 Geospatial Data and Service modeling

The conceptual model of ENVIROFI with respect to the geospatial domain relies upon the ISO/OGC-related specifications of the information and service viewpoints of the RM-OA (Usländer (ed.), 2007) and the Sensor Service Architecture (SensorSA) (Usländer (ed.), 2009). The ENVIROFI conceptual model is a meta-model following the principles of the model-driven architecture (MDA) originated by the Object Management Group (OMG). MDA separates the specification of system functionality from the specification of the implementation of that functionality on a specific technology platform (Asadi and Ramsin, 2008).

The ENVIROFI conceptual model specifies the relationships between the basic design elements such as features, interfaces, services and resources as UML meta-classes. This meta-model includes the resource model as an extension of the meta-model for information and services defined by the OGC and the RM-OA for the information and service viewpoints, respectively (see Figure 4-1).

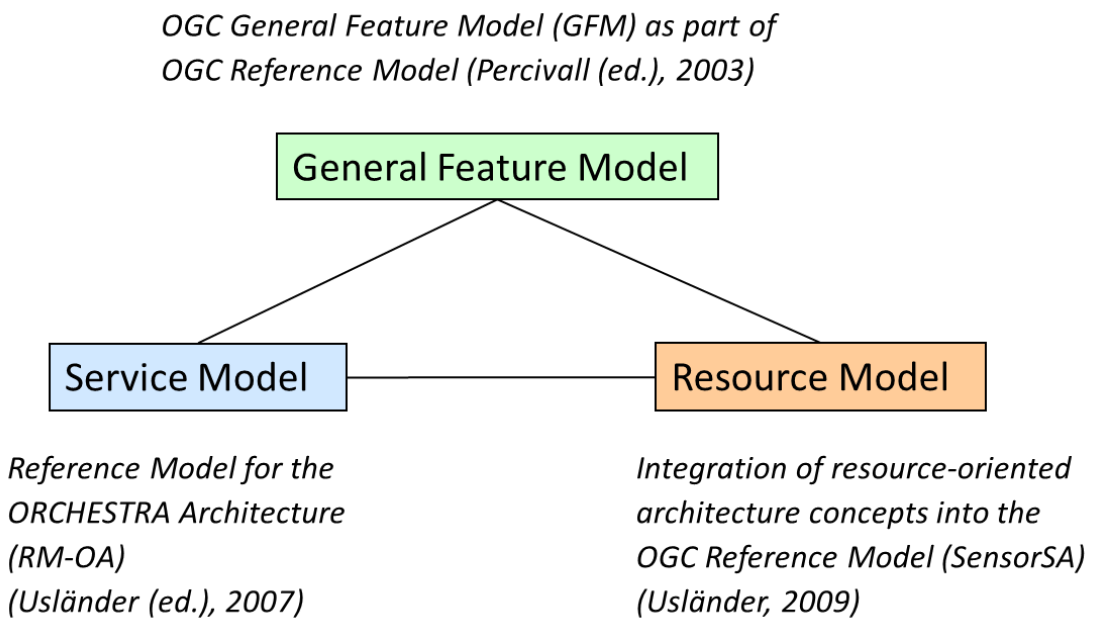

Figure 4-1. Extensions of the ISO/OGC General Feature Model for Services and Resources

Figure 4-2 presents the conceptual model of ENVIROFI for geospatial data and services. It is based upon the ISO General Feature Model (GFM) (ISO 19109:2005). The modelling unit of the GFM is the concept of a feature. Features play a very important role in the design of geospatial applications as they represent entities in the universe of discourse of the users and stakeholders. In general, a feature is an abstraction of a real world phenomenon (e.g. a river or a forest). Features have properties which are usually attributes that describe thematic, spatial or thematic characteristics of a feature. Although rarely used in practice of designing GFM-based application schemas, features may also have operation properties. This allows a system designer to associate dynamic behaviour to features. Features may be associated to each other. This is expressed in terms of role properties of features. For instance, a feature “water body” may be associated to another feature “gauge” with the role “monitors” on the gauge side and the role “is monitored by” on the water body side. If required the act of “monitoring” may itself be modelled as an association feature in order to describe monitoring properties, e.g. to start/stop monitoring or to configure monitoring periods.

The basis for the modelling of ENVIROFI services is provided by the two concepts service and interface. The modelling unit for services is the concept of an interface. A service may have several interfaces and one interface may be applied in several services. For instance, the meta-data of services may be specified in so-called capabilities interface which is common to all services. It delivers a self-description of a deployed service component. Examples are the OGC Web Service Common Implementation Specification (OGC, 2005). An interface has one or more operations which in turn may have one or more (input and output) parameters. The operations and the parameters provide the link to the GFM as both may be properties of features.

A modelling bridge between the information and the service viewpoint is the concept of a resource (Usländer, 2010). On the one hand, it may be modelled as a feature whereby resource representations are attribute properties and links between resources are a specialization of role properties. On the other hand, the set of pre-defined methods that comprise the uniform interface of the resource model are specializations of operations in the service model.

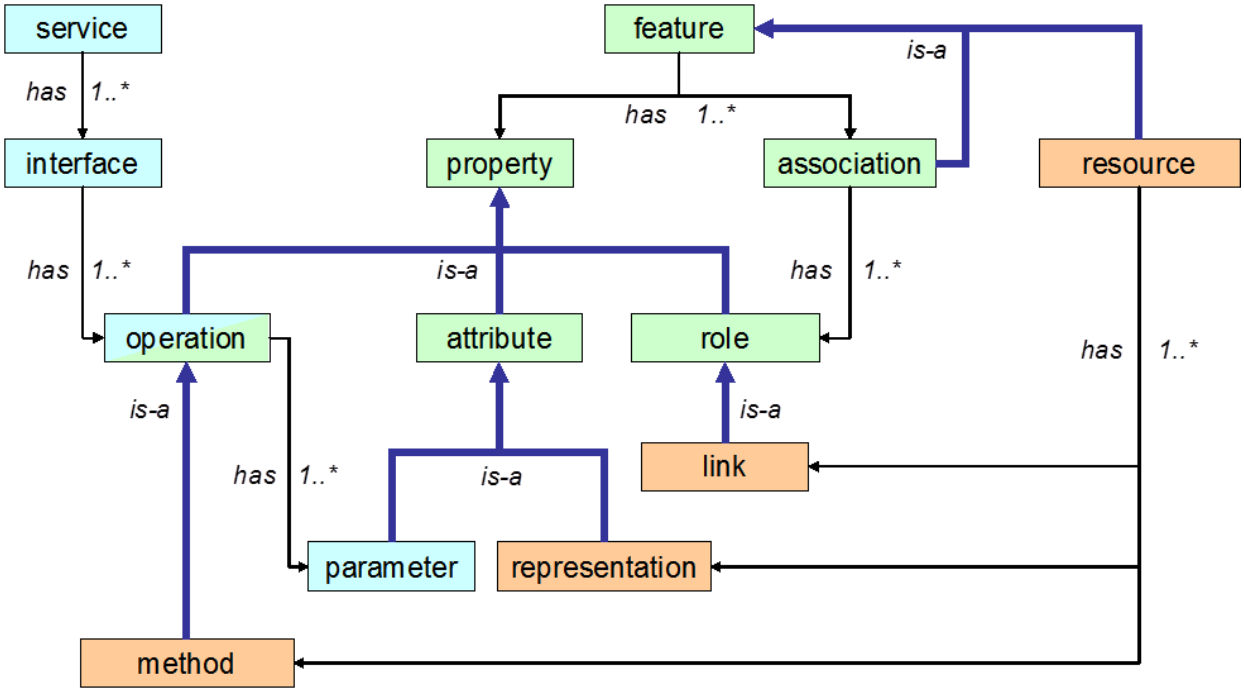

Figure 4-2. ENVIROFI Conceptual Model for the Geospatial Domain

The basic idea of this resource model is derived from the Representational State Transfer (REST) architectural style for distributed hypermedia systems as conceived by Fielding (2000). REST was used to guide the design and development of the architecture for the modern Web. Engineers of distributed systems usually discuss resource-orientation together with its realization in a Web environment, i.e., based on the basic technologies of the World Wide Web. Richardson and Ruby (2007) describe a resource-oriented architecture as a "way of turning a problem into a RESTful Web service: an arrangement of URIs, HTTP and XML that works like the rest of the Web". In contrast, this resource model abstracts from the technological implications, and understands resource-orientation as a modelling approach to support the analysis and design phase.

Hence, the ENVIROFI Resource Model is an abstraction from the technological aspects of RESTful Web services.

4.2.2 FI-WARE Data, Context, Event and Event Object Concepts

This section provides examples of domain-independent conceptual models as provided by the of the FI-WARE architecture draft14. The FI-WARE architecture chapter "Data/Context Management" provides an overview of basic data-related concepts15. These are:

- Data in FI-WARE refers to information that is produced, generated, collected or observed that may be relevant for processing, carrying out further analysis and knowledge extraction. The structure associated to a data element is represented in Figure 4-3.
    - "Value" of the data element is defined as a sequence of one or more <name, type, value> triplets (data element attributes)
    - Optional (semantic) meta-data linked to attributes in a data element can be used to add

[14] http://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/FI-WARE_Architecture_%28PRELIMINARY%29

[15] Note: It is currently unclear if these concepts will be used in other FI-WARE chapters or not.

explicit semantic/meaning to the data.

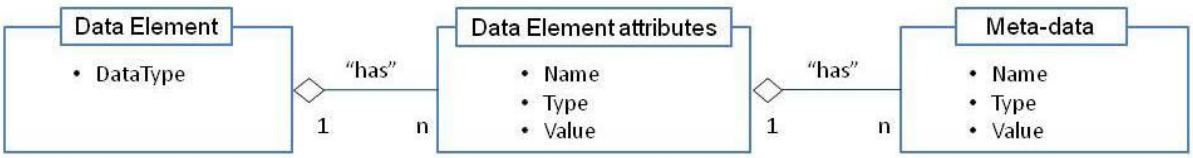

Figure 4-3. FI-WARE Data Element Structure Model

- Context in FI-WARE is represented through context elements. A context element extends the concept of data element by associating an EntityId and EntityType to it, uniquely identifying the entity (which in turn may map to a group of entities) in the FI-WARE system to which the context element information refers. In addition, there may be some attributes as well as meta-data associated to attributes that may be (?) defined as mandatory for context elements.

  The structure of a context element is represented in Figure 4-4.

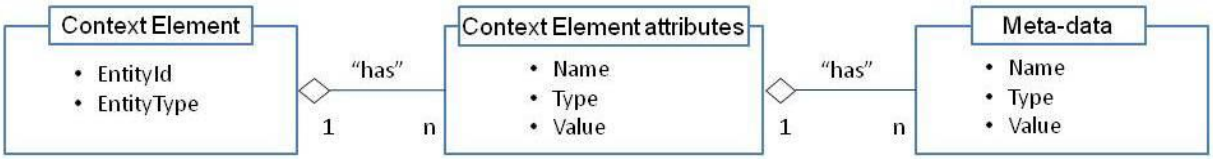

Figure 4-4. FI-WARE Context Element Structure Model

- An **event** is an occurrence within a particular system or domain; it is something that has happened, or is contemplated as having happened in that domain.
  - Events typically lead to creation of some data or context element, thus enabling that information describing or related to events be handled by applications or event-aware FI-WARE GEs (e.g., the Publish/Subscribe Broker GE, when handling update/notifications, or the Complex Event Processing GE).
  - It is common to refer to data/context elements related to events simply as "events" while describing the features of, or the interaction with, event-aware FI-WARE GEs. For convenience, we also may use the terms “data event” and “context event”. A “data event” refers to an event leading to creation of a data element, while a “context event” refers to an event leading to creation of a context element.

- The term **event object** refers to a programming entity that represents such an occurrence (event) in a computing system (Etzion and Niblett, 2010). Events are represented as event objects within computing systems to distinguish them from other types of objects and to perform operations on them, also known as event processing.
  - In FI-WARE, event objects are created internally to some GEs like the Complex Event Processing GE or the Publish/Subscribe Broker GE. These event objects are defined as a data element (or a context element) representing an event to which a number of standard event object properties (similar to a header) are associated internally. These standard event object properties still need to be defined within FI-WARE context.

4.3 Basic Data Models

Environmental enablers all require supporting data/information models. Here, our intensions are twofold. On the one hand, we promote a common approach for the modelling of observation-related information models (including metadata and data schemas). On the other hand, we are following a brokering approach for data discovery and access, which allows us to account for a diversity of data models and to translate available information in the desired observation model(s). In the following we detail the data modelling solutions that are required for the implementation of these two mechanisms. These data models comprise the common approach of modelling observations and measurement including specific profiling as well as metadata and data models that can be translated in the scope of the discovery and access broker specific enablers.

4.3.1 Modelling of Observations and Measurements

4.3.1.1 Common Observation Model

Considering the common approach of modelling observations, we aim at a generic common conceptual model for observations and for the description of environmental sensors. This shall include common vocabularies, e.g. for units of measure, and should particularly offer possibilities for including uncertainty and other quality information. In line with and extending the technology report that has been presented in deliverable D6.1.2, this should consider the following inputs:

- ISO/OGC Observations and Measurements (O&M)
- OGC Sensor Mark-up Language (SensorML)
- INSPIRE Generic Conceptual Model with O&M extension
- INSPIRE Data Specifications (e.g. on environmental monitoring facilities)
- Uncertainty Markup Language (UncertML)
- Uncertainty conventions for the network Common Data Form (netCDF-U)
- Quality aware visualisation for the Global Earth Observation System of Systems (GeoViQua)
- W3C Semantic Sensor Networks Ontology
- SI Unit System
- NASA SWEET Ontologies[16].

4.3.1.2 Common Observation Model – VGI Profile

This profile of the common conceptual observation model is tailored towards user contributed content, especially Volunteered Geographic Information (VGI) and VGI Sensing. This includes the definition of specific vocabularies, e.g. for human surveyors and citizen observatories. Again considering the technology review, this should consider the following inputs:

- OGC/ISO O&M
- OGC SensorML
- W3C Semantic Sensor Networks Ontology (SSNO)[17].

[16] http://sweet.jpl.nasa.gov/

[17] http://purl.oclc.org/NET/ssnx/ssn

4.3.1.3 Common Observation Model and Profiles – Encoding

These specifications provide the encoding rules required for the common conceptual observation model and the associated device descriptions and all derived profiles, taking into account different formats. It still has to be investigated if we also require corresponding URI schemas (e.g. for supporting Linked Data, see above). This is considering:

- W3C eXtensible Markup Language (XML)
- W3C Resource Description Framework (RDF)
- W3C Web Ontology Language (OWL)
- OGC/ISO Geography Mark-up Language (GML) – XML encoding.

4.3.1.4 Observation Model – Biodiversity

Dedicated profile of the common observation model for matching the requirements of the biodiversity sector, this might re-use the VGI profile. It also includes specific vocabularies of the extension of existing vocabularies, e.g. for describing particular Features of Interest or Observed Properties (such as species occurrences). This should particularly account for INSPIRE Data Specifications (e.g. on bio-geographical regions, habitats and biotopes, and species distribution), see also deliverable D1.2.1.

4.3.1.5 Observation Model – Air Quality, Allergens and Meteorology

Dedicated profile of the common observation model for matching the requirements of the Air Quality, Allergens and Meteorology sectors, this might re-use the VGI profile. It also includes specific vocabularies of the extension of existing vocabularies, e.g. for describing particular Features of Interest or Observed Properties. This should particularly account for INSPIRE Data Specifications (e.g. on atmospheric conditions, and meteorological geographical features).

4.3.1.6 Observation Model – Marine

Dedicated profile of the common observation model for matching the requirements of the marine sector, this might re-use the VGI profile. It also includes specific vocabularies of the extension of existing vocabularies, e.g. for describing particular Features of Interest or Observed Properties. This should particularly account for INSPIRE Data Specifications (e.g. on hydrography, oceanographic geographical features, sea regions, and energy resources).

4.3.2 Data Models for Brokering Support

In the environmental domain several metadata and data models/encodings based on specifications from standardization bodies or communities-of-practice are adopted (e.g. Global Biodiversity Information Facility (GBIF) in the biodiversity domain, THREDDS/NetCDF-CF in the Meteorological/Ocean domain). ENVIROFI addresses this heterogeneity through a brokering approach. The discovery and access broker specific enablers currently support the following models, again in line with and extending the technology report that has been presented in deliverable D6.1.2 (others can be added):

- OGC Web Coverage Service (versions 1.0, 1.1, 1.1.2)
- OGC Web Map Service (versions 1.3.0, 1.1.1)
- OGC Web Feature Service (version 1.0.0)
- OGC Web Processing Service (version 1.0.0)

- OGC Sensor Observation Service (version 1.0.0)
- OGC Catalogue Service Web (version 2.0.2 Core with ISO Application Profile 1.0, ebRIM/CIM, ebRIM/EO, CWIC application profiles)
- WAF Web Accessible Folders (version 1.0)
- Thematic Real-time Environmental Distributed Data Services (THREDDS) (versions 1.0.1, 1.0.2)
- THREDDS-NCISO (versions 1.0.1, 1.0.2). ncISO is a command-line utility for automating metadata analysis and ISO metadata generation for THREDDS Catalogues
- THREDDS-NCISO-PLUS (versions 1.0.1, 1.0.2). THREDDS-NCISO-PLUS: uses both NCISO and THREDDS metadata
- CDI – Common Data Index (versions 1.04, 1.3, 1.4, 1.6)
- Global Biodiversity Information Facility (GBIF)
- OpenSearch (version 1.1)
- Open Archives Initiative - Protocol for Metadata Harvesting (OAI-PMH) (version 2.0 supporting ISO19139 and Dublin core formats)
- Network Common Data Form – Climate and Forecast (NetCDF-CF) (version 1.4)
- NetCDF Markup Language – Climate and Forecast (NCML-CF)
- ISO19115-2 Geographic information – Metadata
- GeoRSS (version 2.0)
- Global Disaster Alert and Coordination System (GDACS)
- Data Interchange Format (DIF) File system.

4.4 Approaches to Enable Semantic Interoperability

Classical Spatial Data Infrastructures (SDI), such as those promoted under the umbrella of INSPIRE by building upon standardisation activities of ISO/TC 211 Geographic Information and the Open Geospatial Consortium (OGC), regulate the spatial representation of relevant real-world objects. These representations can be published by applying the Geography Markup Language (GML). Moreover, strictly speaking, the ISO 19100 and OGC series of standards for geographic information themselves can be seen as a common ontology for geographic information concepts, and OWL (Web Ontology Language) descriptions of a subset of these standards have been made available.

For data to be interchanged in a meaningful manner, an additional level of semantic interoperability is needed. Also, semantic heterogeneity presents an obstacle for several activities related to open environment data. Below, we point to solutions developed for overcoming these obstacles and thus enabling semantic interoperability during metadata creation and discovery and during access and use of environmental data. Finally, we illustrate some first efforts toward the integration of the LOD paradigm into SDI and outline the most central information models for the ENVIROFI project.

4.4.1 Semantic Interoperability during Metadata Creation and Discovery

Environmental data represent a category of resources that cannot be easily indexed and retrieved through general-purpose search engines because of their non-textual nature. Therefore, spatial data infrastructures such as INSPIRE typically employ solutions based on annotating data sets with metadata and related discovery mechanisms.

In the context of resource annotation and discovery, research on Knowledge Organisation Systems (KOS) proved that it is possible to take advantage of the Semantic Web infrastructure in a lightweight,

easily implementable fashion. The Simple Knowledge Organisation System (SKOS) constitutes the main output of this research thread.

Since 2010, a series of SKOS thesauri for the geospatial domain has been collected, translated if necessary, and harmonised (Fugazza, 2011a) in the context of INSPIRE. Currently, the reference thesauri that are provided are the following:

- GEneral Multilingual Environmental Thesaurus (GEMET)
- INSPIRE Feature Concept Dictionary (IFCD)
- INSPIRE glossary
- INSPIRE Spatial Data Themes
- GEOSS Societal Benefit Areas (SBAs)
- ISO 19119 Geographic Services Taxonomy
- GEOSS Earth Observation Vocabulary
- NASA's Global Change Master Directory (GCMD) Science Keywords

Albeit comprehensive enough as general-purpose terminology, these thesauri may fall short of providing the terms that specific domains may require. Because of this, thematic thesauri have been added to address specific needs of metadata creators, such as the vocabulary on drought that has been developed in the context of the GEOSS initiative. Also, most of these have been harmonised with each other by domain experts that validated and tuned automatically generated mappings (Fugazza and Vaccari, 2011) before being deployed as a SPARQL endpoint. The resulting repository of controlled vocabularies is being used by applications covering a variety of use cases, ranging from resource annotation to discovery.

4.4.2 Enabling Data Interoperability through Harmonized Specifications

Even after successfully discovering appropriate data, the heterogeneity of data models, formats and vocabularies of environmental data (which is provided by a wide range of data providers) may still present obstacles for data consumers. It is one of the main goals of ENVIROFI to overcome these obstacles and enable consumers—humans as well as systems—to access, use and unambiguously interpret environmental data. To reach this goal and thus making it easier and more efficient to exchange environmental data in a cross-border or pan-European context, ENVIROFI will benefit from harmonised specifications as defined by INSPIRE; particularly the work related to observations and measurements, which is currently in its final phase (stable versions to be expected by mid-April 2012). In the following, we describe the main components and principles of these specifications as well as the tools for their development and implementation and illustrate their relevance to the domain of linked data.

4.4.2.1 Conceptual data models

The data models describe the spatial objects and their properties and relationships for the different spatial data themes. Commonly, the models for all themes are managed in a common UML repository, which makes it easy to establish links between spatial object types in different themes.

4.4.2.2 Harmonised vocabularies

One main obstacle for interoperability is the usage of free text properties in environmental data, in particular in a multi-lingual context such as that of a European data infrastructure. Establishing harmonised vocabularies or code lists that can be used for data exchange is therefore a key aspect of the INSPIRE data specification work and should also be advertised by ENVIROFI.

4.4.2.3 Encoding

In INSPIRE, and in most national and regional SDIs, currently, specific GML-profiles, are promoted as the standard encoding. However, since the conceptual models are independent of concrete encodings, it is also possible to derive other encodings from them. For example, since it has already been shown that GML is in fact isomorphic to RDF, there is no technological barrier for creating alternate INSPIRE encodings for exposing linked data (Schade and Cox, 2010).

4.4.2.4 Location

Location is an important element in all environmental data models. Location is a powerful concept, because it ”spatially enables” the data by allowing analyses on different data sets based on their spatial location (e.g. overlays, intersections, buffers or spatial joins), and would also bring additional benefits to the domain of linked data. The INSPIRE data models suggest four ways to specify the location of a spatial object, through

1. direct coordinates, e.g. as points, lines or polygons,
2. a geographical name (e.g. “New York State “New York City” or “Central Park”),
3. reference to another spatial object, e.g. to an administrative unit (e.g. Yorkshire), or
4. a linear reference to a network link (e.g. a road).

4.4.2.5 Registries

Registers are important components for enabling interoperability in (environmental) information infrastructures. They provide unique and persistent identifiers for a number of different types of information items and allow the consistent management of different versions of register items. By using these identifiers in data and metadata, references to specific information items (e.g. terms from a controlled vocabulary, coordinate reference system or a unit of measure) are made unique and unambiguous. This is also a crucial requirement for linked data (see also below). Furthermore, registers can provide a source of information for developers of information systems and end users by providing definitions, descriptions and other information about the register items (e.g. on the data models and schemas used for sharing data). For this use of registers, in the EU context it is crucial that labels, definitions and descriptions are stored in multiple languages.

4.5 ENVIROFI and Linked Data

In the following some first efforts towards the integration of the Linked (Open) Data paradigm into an the ENVIROFI enabler infrastructure is presented.

The essential pillars of Linked Data (Bizer, 2009) are traditional web technologies and use of light-weight techniques for data model representation. The former depends on the use of Uniform Resource Identifiers (URIs) as reference points. A URI may be used to uniquely identify both data and non-data resources (Berners-Lee et al, 1998). Resolvers map a URI to the physical location of the resource, or in the case of non-data resources to a description.

Linked Data is usually implemented as common HTML for human interfaces, plus RDF for links with machine-processable semantics. RDF provides a structure for any form of description, and is the basis of the Semantic Web (Berners-Lee et al, 2001). RDF describes resources in the form of triples (subject-predicate-object) (Klyne and Carroll, 2004). A basic typing mechanism for subjects, predicates and objects is available as RDF-Schema (RDF-S) (Brickley and Guha, 2004). RDF-S allows for extensions in order to specify domain-dependent subtypes, and thus allow for a domain vocabulary in its own namespace. RDF comes with different encodings, one of which RDF/XML. The key elements of RDF/XML for linking are 'rdf:about' (identifiers or anchors) and 'rdf:resource' (pointers or links). Resources become a set in which elements are connected with links. By these means, users can navigate between data like browsing through web pages. Generally, each piece of data contains link(s) to other data. However, leaf nodes or endpoints of the graph may make use of any other format, which may not support linking. Content-negotiation in HTTP allows client applications (like browsers) to negotiate various data representations (Holtman and Mutz, 1998).

Although RDF is recommended for implementing the Linked Data, as a single global model for all data sources, other structured formats can support semantic linking, e.g. GML as introduced by Schade and Cox, 2010).

A first effort towards the integration of the LOD paradigm into the Environmental Usage Area is an <<"Hybrid SPARQL-SQL Approach" as presented below in the Engineering Viewpoint in section 1.1.

4.6 Recommendations

The concept of the Linked Data Web provides a complementary platform to the ENVIROFI communities in making environmental data available and reusable.

Based on the results of a number of complete and on-going EU-funded projects and activities in which the authors are involved, it is concluded that linked data should be promoted as a powerful mechanism for the sharing of environmental resources. To this end, the recommendations provided in Smits (2011) on the establishment of a world location framework, comprising a temporal framework and a semantic framework along with their corresponding common services and tools, are important to facilitate the linking of environmental information in a geospatial context (see Figure 4-5).

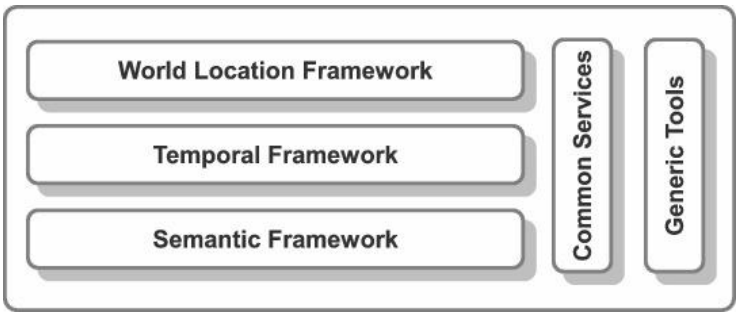

Figure 4-5. Components required for achieving interoperability (Smits, 2011)

More work is needed in terms of supporting tools and infrastructure to make linked data technologies attractive from a user perspective. In the meantime, while the linked data approach is gaining momentum and more and more resources are being exposed as linked data, it is recommended to adopt broker solutions to establish semantic bridges between communities.

5 Computational Viewpoint

5.1 Multi-style Service-Oriented Architecture

The ENVIROFI Environmental Architecture supports the paradigm of a service-oriented architecture (SOA). However, the term SOA has to be defined in the context of a reference model in order to clarify its meaning. ENVIROFI aims at conceptualizing a so-called multi-style SOA. This is a SOA that supports multiple architectural styles and communication patterns such a request/reply messaging, event-driven interactions and resource-oriented services (commonly known as RESTful Web services) following the conceptual model for geospatial data and services as defined in section 4.2.1.

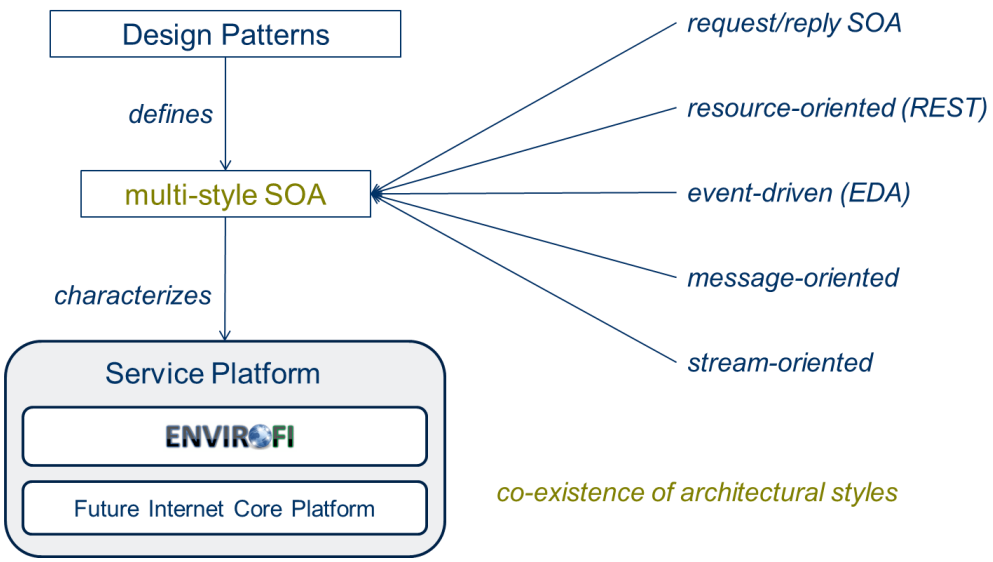

Figure 5-1. Multi-style SOA

The following definitions are used:

- **Design patterns** provide solutions to common problems encountered when applying design principles-and-when establishing an environment suitable for implementing logic designed in accordance with service-orientation principles (Erl, 2008)[18]
- An Architectural Style is a coordinated set of **architectural constraints** that restricts the roles/ characteristics[features] of **architectural elements** and the **allowed relationships** among those elements (Fielding, 2000)
- A service-oriented architectural style is a coordinated set of **architectural constraints** that restricts the roles, characteristics and the **allowed relationships** of **services** and **service consumers.**

The ENVIROFI Environmental Architecture claims to rigorously define such a multi-style SOA based upon comprehensive SOA design patterns such as those defined by (Erl, 2008).

Figure 5-2 illustrates the relationships between these concepts (coloured in grey) as an extension of the geospatial conceptual model presented above in the Information Viewpoint in Figure 4-2.

[18] http://www.soapatterns.org

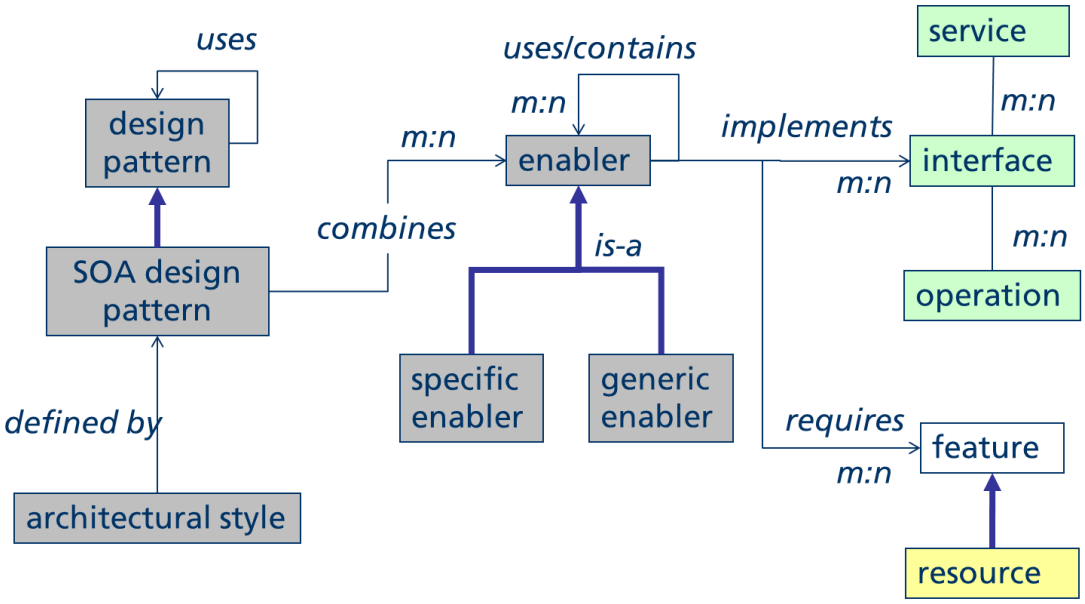

Figure 5-2. Relationships between the Concepts as used in FI-PPP

It presents the following ideas:

- ENVIROFI defines an enabler as “a software component in an implementation architecture with a well-defined interface that fulfills a given set of functional, informational and qualitative requirements”. Hence, with respect to the geospatial conceptual model of Figure 4-2 an enabler implements one or more interfaces of services and, for such an implementation, requires one or more features (e.g. to be provided or referenced as operation parameters).
- An enabler may use and/or contain one or more other enablers.
- According to the FI-PPP approach, enablers are classified into (domain-independent) generic enablers and (domain-specific, i.e. usage-area specific) specific enablers.
- A SOA design pattern is a specialization of the general software concept of design patterns.
- SOA Design patterns may be realized by combining one or more enablers.
- Finally, following the ENVIROFI approach, an architectural style is defined by means of SOA design patterns.

  Note: Definitions of such architectural styles will be contained in the next version of the ENVIROFI Environmental Architecture (this deliverable).

5.2 Service Classification

The ENVIROFI Environmental Architecture supports and actively contributes to the service classification approach that is being defined in the CEN Technical Report 15449 and the revision of ISO 19119. This includes both an architecture-based and a life-cycle-based categorisation of services.

Therefore, the current draft version of in the CEN Technical Report 15449 is provided as confidential annex to this deliverable D4.2.

5.3 ENVIROFI Logical Architecture

The ENVIROFI logical architecture is being extended and further refined from the initial ENVIROFI architecture as described in the ENVIROFI deliverable D6.1.1. This is being done by incorporating more details on the various core platform generic enablers, and also by identification and specification of geospatial and environment-specific enablers required beyond the generic enablers and the functionality of relevant applications.

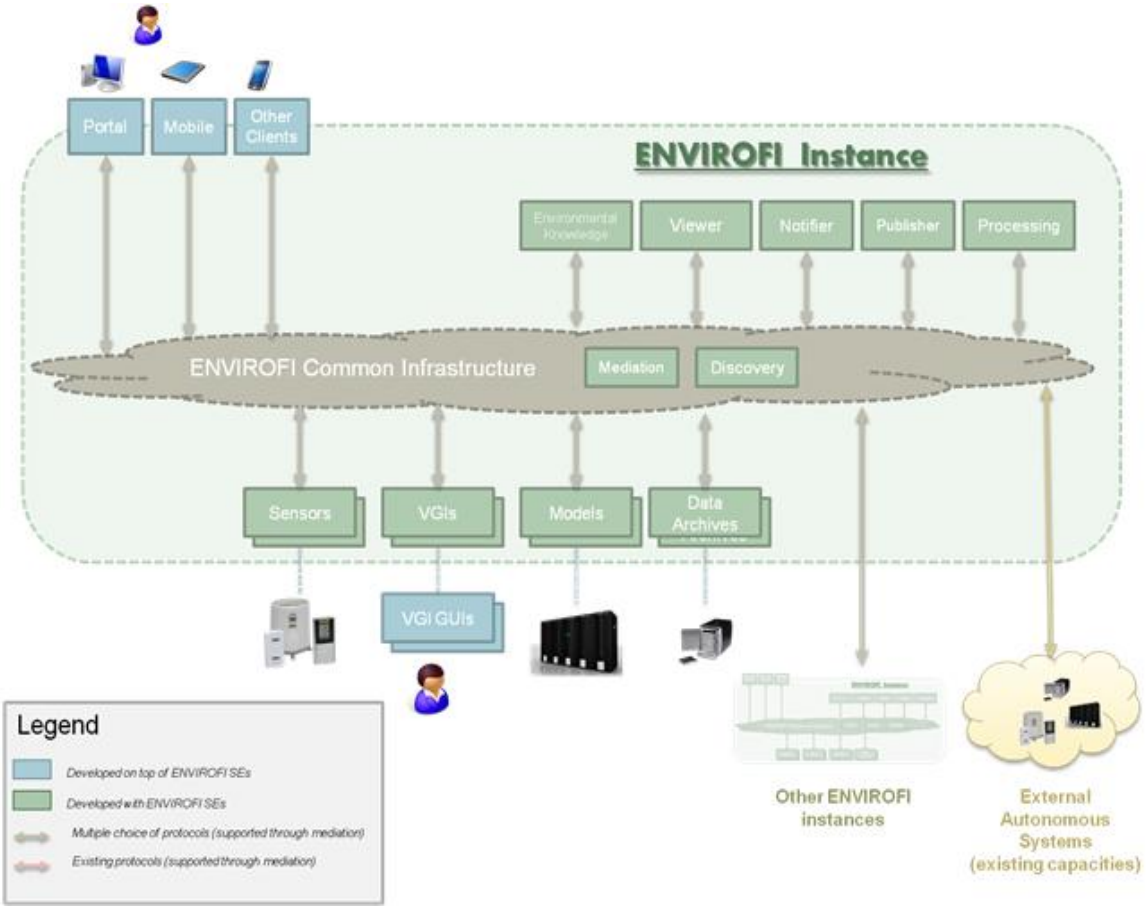

Figure 5-3. Initial Sketch of the ENVIROFI architecture

The following figure shows a refinement of the initial architecture sketch, with seven specific-enabler areas of ENVIROFI and seven generic enabler areas of FI-WARE.

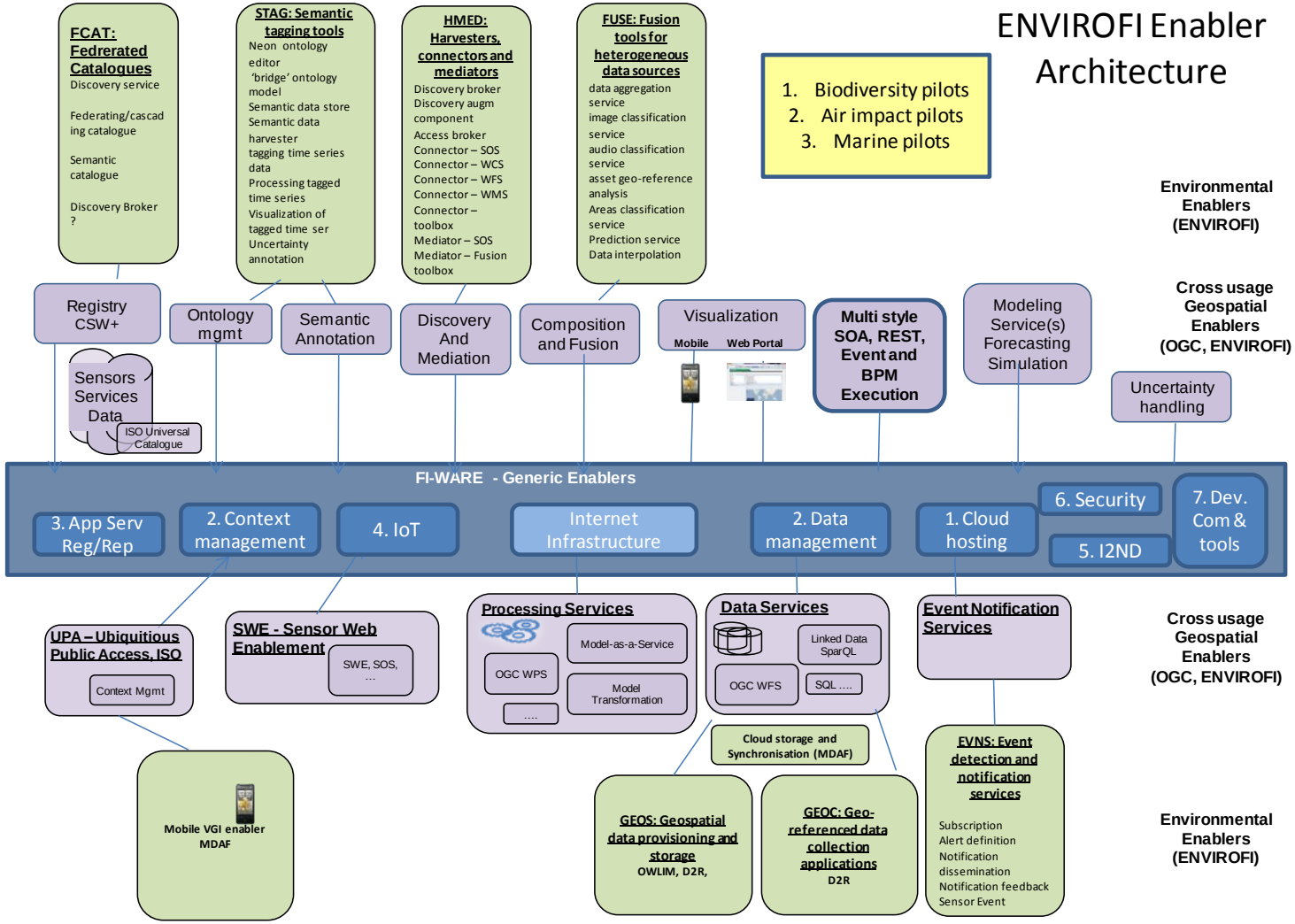

Figure 5-4. ENVIROFI Enabler Architecture

The ENVIROFI architecture is further refined in three different groups of enablers. The core part is related to extensions of FI-WARE generic enablers. Furthermore, ENVIROFI proposes a distinction between geospatial enablers to be used across the FI-PPP usage areas, and environment-specific enablers.

The core generic enablers of FI-WARE initially have a set of 7 areas (chapters) with an initial set of 46 core platform generic enablers which extend the general Internet infrastructure. The following seven categories of generic enablers have been identified by the FI-WARE project:

1. Cloud Hosting
2. Data management and context management
3. Internet of Things (IoT) Services Enablement
4. Applications/ Services Ecosystem & Delivery Framework
5. Security
6. Interface to Networks and Devices (I2ND)
7. Developers' Community and Tools

Beyond these the ENVIROFI project has identified 45 environment-specific enablers in seven categories as further described in D5.1. The following seven categories of generic enablers have been identified by the ENVIROFI project:

1. FCAT: Federated Catalogues
2. STAG: Semantic tagging tools
3. HMED: Harvesters, connectors and mediators
4. FUSE: Fusion tools for heterogeneous data sources
5. EVNS: Event detection and notification services
6. GEOC: Geo-referenced data collection applications
7. GEOS: Geospatial data provisioning and storage

In addition to these there is some further elaboration now on a possible category for a mobile voluntary geographic information (VGI) enabler and a supporting cloud storage and synchronisation framework.

The ENVIROFI specific enablers are partially related to geospatial enablers, potentially cross-domain, from the last 15 years of standardisation of geospatial services in ISO/TC211 and OGC. The initial set of 45 specific enablers is described further in the ENVIROFI deliverable D5.2.1

The geospatial enablers are derived from geospatial services and data models that were already standardised or comprise standards-in progress. They are initially identified in the following 14 different groups, derived service groups of TR 15449 and ISO 19119 which are classified according to a lifecycle or architecture view. They reflect existing or emerging OGC and ISO/TC211 services.

1. Registries, repositories and catalogues
2. Ontology management
3. Semantic annotation
4. Discovery and mediation
5. Composition and fusion
6. Visualisation and presentation services

7. Multi-style SOA (communication/execution)
8. Modeling services
9. Uncertainty handling
10. Event Notification Services
11. Data Services
12. Processing services
13. Sensor Web Enablement services (from OGC)
14. Ubiquitous public access (ISO/TC211 standard in progress)

Note: In the further refinement and detailed identification of the FI-PPP generic (core platform), and the ENVIROFI geospatial and environment-specific enablers, it will be analysed which of these three groups an enabler should belong to, and which relationships between similar enablers from the different groups exist in terms of possible extensions or variations.

6 Technology Viewpoint

FI-WARE has so far not published the technical specifications of the FI-WARE implementation. However, some information in this direction is already available in the draft FI-WARE architecture description[19]. This section gives an overview of the technologies and standards relevant to FI-WARE. Table 6-1 provides a summary ordered by the architectural chapters that is based on the information found in the draft architecture document and the documents directly referenced from this document.

Name	Chapter	Description	ENVIROFI equivalent[20]
OCCI	Cloud	The Open Cloud Computing Interface (OCCI) is a RESTful protocol and API for the management of cloud service resources. It comprises a set of open community-lead specifications delivered through the Open Grid Forum. OCCI was originally initiated to create a remote management API for IaaS model based Services. It has since evolved into a flexible API with a strong focus on integration, portability, interoperability and innovation while still offering a high degree of extensibility. More information: http://ogf.org/documents/GFD.183.pdf http://ogf.org/documents/GFD.184.pdf http://ogf.org/documents/GFD.185.pdf	-
Open-Stack	Cloud	Ubiquitous open source cloud computing platform for public and private clouds. OpenStack includes three "core projects: (1) COMPUTE: software and standards for large-scale deployments of automatically provisioned virtual compute instances. (2) OBJECT STORAGE: software and standards for large-scale, redundant storage of static objects. (3) IMAGE SERVICE: provides discovery, registration, and delivery services for virtual disk images.	-

[19] http://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/FI-WARE_Architecture

[20] **NOTE**: Some equivalence relations are currently under discussion. In this vein, they are noted with the symbol '*'

Name	Chapter	Description	ENVIROFI equivalent[20]
		More information: http://www.openstack.org/projects/	
CDMI	Cloud	Cloud Data Management Interface (CDMI) may be used to create, retrieve, update, and delete objects in a cloud. The features of the CDMI include functions that: • allow clients to discover the capabilities available in the cloud storage offering, • manage containers and the data that is placed in them, and • allow metadata to be associated with containers and the objects they contain. More information: http://cdmi.sniacloud.com/	-
OVF	Cloud	Open Virtualization Format (OVF) is a packaging standard designed to address the portability and deployment of virtual appliances. OVF enables simplified and error-free deployment of virtual appliances across multiple virtualization platforms. More information: http://www.dmtf.org/standards/ovf	-
RIF-BLD	Cloud	Rule Interchange Format Basic Logic Dialect (RIF-BLD); used to define SLA targets and elasticity rules in Cloud Service Manager GE More information: http://www.w3.org/TR/2010/REC-rif-bld-20100622/	-
MongoDB	Data / Context	For data sets smaller than 0.5 Terabytes the BigData Analysis GE will make use of a document orientated storage system based on NoSQL. The interface is to be compatible with MongoDB. This component will be used to provide a high-availability store for querying data.	CouchDB

Name	Chapter	Description	ENVIROFI equivalent[20]
Hadop	Data / Context	The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using a simple programming model. It is designed to scale up from single servers to thousands of machines, each offering local computation and storage. Rather than rely on hardware to deliver high-avaiability, the library itself is designed to detect and handle failures at the application layer, so delivering a highly-availabile service on top of a cluster of computers, each of which may be prone to failures. More information: http://hadoop.apache.org/	-
MLP	Data / Context	Mobile Location Protocol (MLP) interface facilitates many services to retrieve the position of a compatible target mobile terminal for various types of applications. The target mobile terminal position is retrieved using AGPS, WiFi and Cell-Id positioning technologies. More information: Open Mobile Alliance, specification OMA-TS-MLP-V3_2-20110719-A	aGPS*
SUPL	Data / Context	Secure User Plane Location Protocol (SUPL), More information: Open Mobile Alliance, specification OMA-TS-ULP-V2_0-20111222-D	-
RRLP	Data / Context	Radio Resource LCS Protocol (RRLP), More information: 3GPP, specification 3GPP TS 44.031 V9.2.0 (2010-03)	-
RTP	Data / Context	RTP: A Transport Protocol for Re al-Time Applications provides end-to-end network transport functions suitable for applications transmitting real-time data, such as audio, video or simulation data, over multicast or unicast network services. RTP does not address resource reservation and does not guarantee quality-of-service for real-time services. More information: http://tools.ietf.org/html/rfc3550	-

Name	Chapter	Description	ENVIROFI equivalent[20]
EXI	Data / Context	Efficient XML Interchange (EXI) Format is a very compact representation for the Extensible Markup Language (XML) Information Set that is intended to simultaneously optimize performance and the utilization of computational resources. The EXI format uses a hybrid approach drawn from the information and formal language theories, plus practical techniques verified by measurements, for entropy encoding XML information. Using a relatively simple algorithm, which is amenable to fast and compact implementation, and a small set of datatype representations, it reliably produces efficient encodings of XML event streams More information: http://www.w3.org/TR/2011/REC-exi-20110310/	*
ONVIF	Data / Context	The ONVIF Network Interface specification defines the network device types Network Video Transmitter (NVT), Network Video Decoder (NVD), Network Video Storage (NVS) and Network Video Analytics (NVA). The specification includes detailed service requirements and interface defintion. More information: http://www.onvif.org/Documents/Specifications.aspx	-
XPath	Data / Context	XML Path Language (XPath) is an expression language that allows the processing of values conforming to the data model defined in XQuery 1.0 and XPath 2.0 Data Model. The result of an XPath expression may be a selection of nodes from the input documents, or an atomic value, or more generally, any sequence allowed by the data model. The name of the language derives from its most distinctive feature, the path expression, which provides a means of hierarchic addressing of the nodes in an XML tree. More information: http://www.w3.org/TR/xpath20/	XPath

Name	Chapter	Description	ENVIROFI equivalent[20]
MPQF	Data / Context	MPEG Query Format (MPQF) is an XML based query language and intended to be used in a distributed multimedia retrieval services (MMRS). Beside the standardization of the query language, MPQF specifies the service discovery and the service capability description. Here, a service is a particular system offering search and retrieval abilities (e.g. image retrieval). More information: ISO/IEC 15938-1:2002 - Information technology -- Multimedia content description interface -- http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=46427	-
Linked Data	Data / Context	Linked Data is about using the Web to connect related data that wasn't previously linked, or using the Web to lower the barriers to linking data currently linked using other methods. More specifically, Wikipedia defines Linked Data as "a term used to describe a recommended best practice for exposing, sharing, and connecting pieces of data, information, and knowledge on the Semantic Web using URIs and RDF. More information http://linkeddata.org/	Linked Data
RDF	Data / Context	RDF is a standard model for data interchange on the Web. RDF has features that facilitate data merging even if the underlying schemas differ, and it specifically supports the evolution of schemas over time without requiring all the data consumers to be changed. More information: http://www.w3.org/RDF/	RDF
OWL	Data / Context	The OWL Web Ontology Language is an ontology language for the Semantic Web with formally defined meaning. OWL ontologies provide classes, properties, individuals, and data values and are stored as Semantic Web documents. OWL ontologies can be used along with information written in RDF, and OWL ontologies themselves are primarily exchanged as RDF documents. More information: http://www.w3.org/TR/owl2-overview/	OWL

Name	Chapter	Description	ENVIROFI equivalent[20]
Sesame	Data / Context	Sesame is a de-facto standard framework for processing RDF data. This includes parsing, storing, inferencing and querying of/over such data. It offers an easy-to-use API that can be connected to all leading RDF storage solutions. More information: http://www.openrdf.org/documentation.jsp	Sesame*
OWLIM	Data / Context	OWLIM is a family of semantic repositories, or RDF database management systems, with the following characteristics: • native RDF engines, implemented in Java • delivering full performance through both Sesame and Jena • robust support for the semantics of RDFS, OWL 2 RL and OWL 2 QL • best scalability, loading and query evaluation performance More information: http://www.openrdf.org/documentation.jsp	OWLIM*
SPARQL	Data / Context	The SPARQL Protocol and RDF Query Language (SPARQL) is a query language and protocol for RDF. This document specifies the SPARQL Protocol; it uses WSDL 2.0 to describe a means for conveying SPARQL queries to an SPARQL query processing service and returning the query results to the entity that requested them. More information: http://www.w3.org/TR/rdf-sparql-protocol/	SPARQL
ETSI M2M	IoT	ETSI Machine-to-Machine (M2M) communications is an application agnostic standard for M2M communication. It contains an overall end to end M2M functional architecture, identifies the functional entities and the related reference points. More information: http://docbox.etsi.org/M2M/Open/Latest_Drafts/	OGC SWE*

Name	Chapter	Description	ENVIROFI equivalent[20]
OMA NGSI Context Management	IoT	The OMA NGSI Context Management component provides the NGSI-9 and NGSI-10 interfaces to manage Context Information about Context Entities. The purpose of NGSI-9 is to exchange information about the availability of Context Information, while NGSI-10 is desiged for exchanging the Context Information itself. A Context Entity is any principal and object, which has a state. This state can be described using Context Information. Context Entities could be users, devices, places, buildings, and many other (including virtual objects). Context Information is any volatile or persistent information, which describes a state of a Context Entity. Context Information can be measured by sensors, manually set by humans, derived from operations on handsets or terminals, inferred from other information, or requested from databases. More information: http://www.openmobilealliance.org/Technical/release_program/docs/CopyrightClick.aspx?pck=NGSI&file=V1_0-20101207-C/OMA-TS-NGSI_Context_Management-V1_0-20100803-C.pdf	DEWS (related to publish/subscribe design pattern)
USDL	Apps	USDL (Uniform Service Description Language) is a platform-neutral language for describing services. USDL is building a layer on top of technical service descriptions such as WSDL, which captures the information necessary to manage services in the business framework across the whole service lifecycle. More information: http://linked-usdl.org/	*
JSON	Apps, Data/ Context	JSON (JavaScript Object Notation) is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language, Standard ECMA-262 3rd Edition - December 1999. JSON is a text format that is completely language independent but uses conventions that are familiar to programmers of the C-family of languages, including C, C++, C#, Java, JavaScript, Perl, Python, and many others. These properties make JSON an ideal data-interchange language. More info: http://www.json.org/	JSON
Turtle	Apps		

Name	Chapter	Description	ENVIROFI equivalent[20]
MDL[21]	Apps	A mashup is the composite application created by the Composition Editor GE, deployed into the Composition Execution Engine GE. Mashups are described by means of the mashup description language (MDL) More information: https://github.com/Wirecloud/wirecloud/blob/develop/docs/source/mashup_template.xsd	-
GDL	Apps	A mashup is a remix and integration of several gadgets/widgets, that is, atomic user interfaces frames that allow accessing to backend services and offer a simple but complete functionality. Gadgets API and functionality must be also described by means of the Gadget Description Language (GDL). More information: https://github.com/Wirecloud/wirecloud/blob/develop/docs/source/gadget_template.xsd	-
WebIDL	I2ND	WebIDL is the interface definition language of choice for JavaScript based environments. WebIDL was defined by the W3C standards body and has been used to define many key technologies. As the CDI Generic Enabler will implementing JavaScript based reference implementation all of the functional blocks defined using WebIDL More information: http://www.w3.org/TR/WebIDL/	*
FMC	I2ND	Interfaces which are accessible directly from other GE's and are not based on JavaScript shall be described using FMC (Fundamental Modelling Concepts) More information: http://www.fmc-modeling.org/	*

[21] https://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/FIWARE.ArchitectureDescription.Apps.CompositionEditor

Name	Chapter	Description	ENVIROFI equivalent[20]
ETICS	I2ND	ETICS (Economics and Technologies for Inter-Carrier Services) is a European collaborative research project within the ICT theme of the 7th Framework Programme of the European Union that contributes to the objective "Network of the Future" of the Work Programme. ETICS aims at creating a new ecosystem of innovative QoS-enabled interconnection models between Network Service Providers allowing for a fair distribution of revenue shares among all the actors of the service delivery value-chain. To achieve these objectives, ETICS will analyse, specify and implement new network control, management and service plane technologies for the automated end-to-end QoS-enabled service delivery across heterogeneous carrier networks. More information: https://www.ict-etics.eu/home.html	*
SUPL	Data/ Context , I2ND	OMA Secure User Plane Location (SUPL) is an Enabler which utilizes existing standards where available and possible, to transfer assistance data and positioning data over a User Plane bearer, such as IP, to aid network and SUPL Enabled Terminal (SET) based positioning technologies in the calculation of a SET's position. SUPL includes but is not limited to the definition of a Location User Plane (Lup) Reference Point and corresponding interface between the SUPL Location Platform (SLP) and SET, security functions (e.g., authentication, authorization), charging functions, roaming functions, and privacy functions. SUPL utilizes existing standards where available and possible, and SUPL should be extensible to enabling more positioning technologies as the need arises so that they utilize the same mechanism. More information: http://www.openmobilealliance.org/technical/release_program/supl_v2_0.aspx	aGPS*
OSSIM	Security	Open Source Security Information Management (OSSIM) is the de facto standard Open Source SIEM. The goal of AlienVault's OSSIM is to provide a comprehensive compilation of tools that work together to provide a detailed view over each and every aspect of your networks, hosts, physical access devices, server, etc. More information: http://communities.alienvault.com/community/technical-documentation	*

Name	Chapter	Description	ENVIROFI equivalent[20]
USDL-SEC	Security	Security extension of USDL (in development)	-
OAuth	Security	Open Authorization Protocol is an open standard for authorization.	*
SAML	Security	OASIS Security Assertion Markup Language (SAML) is an XML-based standard for exchanging authentication and authorization data between security domains. The Identity Management GE makes use of SAML (Security Assertion Markup Language) 2.0 for authenticating federated relying parties and, after authenticating the Users on behalf of the federated relying parties in a second step, for informing them that these Users are authorized to access their services. More information: http://saml.xml.org/about-saml	SAML*
OpenID	Security	OpenID is an open standard that describes how users can be authenticated in a decentralized manner More information: http://openid.net/specs/openid-authentication-2_0.html http://openid.net/connect/	*
eID	Security	eID stands for European Identity Cards; the FI-WARE Identity manager will support authentication using eIDs of multiple states More information: https://www.eid-stork.eu/	*
XACML	Security	The OASIS Extensible Access Control Markup Language (XACML) defines a core schema and corresponding namespace for the expression of authorization policies in XML against objects that are themselves identified in XML. XACML enables the use of arbitrary attributes in policies, role-based access control, security labels, time/date-based policies, indexable policies, 'deny' policies, and dynamic policies — all without requiring changes to the applications that use XACML. More information:	GEOXACML

Name	Chapter	Description	ENVIROFI equivalent[20]
		http://xml.coverpages.org/xacml.html	
PPL	Security	The Privacy Policy Language (PPL) is defined to express access and usage control rules. It is based on the XACML standard. It permits to define privacy policies that regulate and specify obligations for the usage of personal information. More information: http://www.primelife.eu/results/documents/153-534d	-

Table 6-1. Recommended Technologies of the FI-WARE Architecture Draft

7 Engineering Viewpoint

7.1 ENVIROFI Environmental Enablers related to FI-WARE chapters

The current list of specific enablers as identified and defined by ENVIROFI (environmental enablers) is provided in the ENVIROFI deliverable D5.2.1.

In an ideal world, all the FI-WARE architectural chapters would be both of great interest to ENVIROFI and orthogonal to our research and development work. In reality, our initial analysis, which has been published at the EnviroInfo 2011 Conference (Havlik et al, 2011) confirmed the interest in the FI-WARE work, but already indicated large overlaps and possible redundancies with two of the FI-WARE architectural chapters. Table 7-1 below summarizes the findings.

Note: a further revision of the ENVIROFI Environmental Architecture will describe how ENVIROFI specific enablers may be mapped to the FI-WARE core platform architecture (resp. their generic enablers).

Chapter	Scope	Relevance for ENVIROFI	Risks and Overlaps
Cloud Hosting	Virtualization of resources at several levels: (1) Infrastructure as a Service (IaaS) enablers facilitate virtualization of the raw compute resources such as storage, servers or network; (2) Platform as a Service (PaaS) level provides a mean to outsource part of the system administration tasks to third parties; and finally (3) the Software as a Service (SaaS) level enablers simplify the task of providing end-users with network centric applications.	FI-WARE addresses three key issues which have so far prevented wide adoption of the cloud technology in Environmental UA: • Quality of Service (QoS); • cross-provider federation; and • control over data and processing whereabouts. These factors should be easily configurable, and negotiated through Service Level Agreements (SLEs) In addition, the Cloud Edge and Object Storage GEs may simplify design of the	This chapter is out of ENVIROFI scope (no significant overlaps). Cloud Hosting functionality promised by FI-WARE is very attractive for the Environmental UA. However, the FI-WARE offering will face the fierce competition from established cloud hosting providers.

Chapter	Scope	Relevance for ENVIROFI	Risks and Overlaps
	In addition, this Chapter also foresees development of two very interesting services: (1) Object Storage GE shall provide the capabilities to store and retrieve complex objects; and (2) the Cloud Edge GE shall provide a mean to instantiate (part of) the cloud infrastructure at clients location.	cloud enabled Environmental Management Systems (EMS).	
Data/ Context Management	This Chapter features a number of generic services that are often found in service oriented applications of the environmental Usage Area, such as: publish/subscribe broker; event processor; various data pre-processing and data analysis services. This Chapter also provides the tools for semantic enablement, location awareness and smart data retrieval, as well as a number of more complex services built on top of these atomic GEs.	From the point of view of the Environmental Usage Area, the most interesting (new) functionality introduced in this Chapter could be the improved location service for mobile and VGI applications. Moreover, the cloud-enabled versions of various data/event analysis and processing services may indeed lead to a superior business proposal as compared to services which weren't initially designed with cloud infrastructure in mind.	Some of the GEs introduced in this Chapter resemble the services which are already available in the Environmental UA. The acceptance of such services will highly depend on the ease of integration in existing service landscape of the Environmental usage area. Furthermore, the GEs providing the user-profiling functionality may lead to ethical (privacy) issues.
Applications and Services Ecosystem and Delivery Framework	This Chapter directly addresses the community needs for carrying existing prototypical solutions into final, deployable components, and establishment of the large marketplace for environmental services. In particular, the combination of a "Store", "Marketplace", "Revenue Sharing" enabler and an "SLA Support" Enabler could grow into a complete solution for federated FI data and service marketplace(s).	The Environmental UA has been quite successful in linking of the individual environmental information systems into trans-national and global networks. However, the international initiatives such as GEOSS or INSPIRE we have so far failed to build internet-enabled marketplace for environmental information and services. This Chapter thus directly addresses the well-known need of the Environmental UA.	This chapter is out of ENVIROFI scope (no significant overlaps) Uptake of the GEs developed within this chapter could be slowed down by technical and/or organisational incompatibilities with existing initiatives of the environmental UA.

Chapter	Scope	Relevance for ENVIROFI	Risks and Overlaps
	Other enablers in this Chapter: "Mediator" GEs can be used to achieve interoperability between future internet services and applications and also allow interfacing to existing enterprise systems. "Service Composition" enablers will allow composing existing services to value added composite services and applications.		
IoT Service Enablement	The Internet of Things (IoT) Service Enablement Chapter introduces a large number of services promoting the integration of information systems and the physical world through ubiquitous networking with embedded systems, RFID, sensors and actuators.	This chapter is to a certain level complementary with the ENVIROFI work, as we do not directly address (hardware) sensors and attenuators in this project. From ENVIROFI point of view, the most interesting (new) aspects of this chapter are: • the standardization of the interfaces to (hardware) sensors and attenuators; and • Machine to Machine communication.	The IoT overlaps with OGC Sensor Web Enablement., and therefore also with the core work of the ENVIROFI. The risk of incompatibility and non-acceptance within Environmental UA is very high, but may be mitigated through dialog between IoT and OGC SWE communities.
Interfaces to Networks and Devices	I2ND will define an enabler space for providing Generic Enablers (GEs) to run an open and standardised network infrastructure. This infrastructure will have to deal with highly sophisticated terminal as well as with highly sophisticated proxies on one side and with the	The I2ND Chapter addresses the need for standardized and interoperable access to physical devices such as smartphones, sensors, actuators or network switches. Main interest of ENVIROFI in this chapter lies in the possibility to dynamically	

Chapter	Scope	Relevance for ENVIROFI	Risks and Overlaps
	network operator infrastructure in itself. This infrastructure will be implemented by network nodes. These nodes will be under direct control of on operator or node functionality will be virtualised – in this case we have a virtual operator.	change the end-to-end QoS on demand. In combination with the QoS functionality introduced in the Cloud chapter, this could provide a low cost solution assuring very high QoS for environmental information systems when needed; e.g. in emergency situations.	
Security	FI-WARE Security GEs provide means to assure Security, Privacy and Trust in Future Internet applications. The Security Chapter is structured into four main modules: (1) security monitoring mechanisms; (2) a set of General Core Security Mechanisms including Identity Management and Privacy solutions; (3) Context-Based Security and Compliance enablers assuring the security mechanisms used by FI applications can be dynamically adjusted to legal and business requirements; and (4) a set of universally discoverable Optional Generic Security Services that will be instantiated at runtime and can be dynamically reconfigured based on the needs of specific scenarios.	"Security" Chapter addresses the community needs for carrying existing prototypical solutions into final, deployable components, and establishment of the trusted and secure marketplace for environmental services. In particular, the concept of Privacy Enhanced user management, authentication and access control introduced in this Chapter may provide a way to enhance the privacy protection in VGI applications, by keeping all privacy related information at the trusted server, while still providing a mean to establish a trust relationship between application users and providers.	This chapter is out of the ENVIROFI scope (no significant overlaps) Main issues which could lower the acceptance within Environmental UA are: (1) support for geo-spatial constraints; and (2) compatibility with existing security solutions used within Environmental UA.

Table 7-1. FI-WARE Architectural Chapters and ENVIROFI

7.2 ENVIROFI Interest in FI-WARE Generic Enablers

With an announcement (March 2012) of a delay in the delivery of the first implementation of the core platform from the FI-WARE project an initiative has been launched to provide further detailed information about the various generic enablers of the different core platform parts through an educational/training session tentatively to take place in May and June 2012. As part of the preparation for this the different use case projects have provided priorities[22] on their interest for the various FI-WARE chapters with corresponding generic enablers. The ENVIROFI interest in the various chapters and enablers is shown below.

7.2.1 Cloud hosting

Cloud hosting has initially defined 9 generic enablers:

Cloud Hosting	ENVIROFI Interest		2
	Release 1 (End July)	Cloud.DCRM	2
		Cloud.SM	1
		Cloud.Edge	3
		Cloud.ObjectStorage	3
	Release 2 (end Sept.)	Cloud.Monitoring	1
		Cloud.CloudEdgeRM	3
		Cloud.MonitoringAnalytics	1
		Cloud.Accounting	1
		Cloud.HybridCloudBroker	3

Figure 7-1. ENVIROFI Interest in Cloud Hosting Enablers

The ENVIROFI interest in Cloud Hosting is medium and in particular high related to ObjectStorage and EdgeRM.

7.2.2 Data/Context Management

Data/Context Management has initially defined 9 generic enablers.

Data/Context Management	ENVIROFI Interest		3
	Release 1	Data.BigData	3
		Data.PubSub	3
		Data.CEP	2
		Data.Location	3
		Data.MetadataPreprocessing	2
		Data.MultimediaAnalysis	2
		Data.QueryBroker	3
		Data.SemanticAnnotation	3
		Data.SemanticSupport	3
	Release 2		

Figure 7-2. ENVIROFI Interest in Data/Context Management Enablers

The ENVIROFI interest in Data/Context Management is high, and in particular high related to BigData,

[22] **Interest Score' rating:** High interest: 3; Medium Interest: 2; Low interest: 1

PubSub event notification and semantic support.

7.2.3 Internet of Things (IoT) Services Enablement

Internet of Things (IoT) Services Enablement has initially defined 6 generic enablers.

Internet of Things (IoT) Services Enablement	ENVIROFI Interest		2
	Release 1	IoT.Backend.DeviceHandler	2
		IoT.Backend.IoTBroker	2
		IoT.Backend.ThingsAndResourcesManageme	2
		IoT.Backend.DeviceFrontend	2
	Release 2	IoT.Backend.ServiceControl	2
		IoT.Backend.ConnectivityManagement	2

Figure 7-3. ENVIROFI Interest in IoT Services Enablers

The ENVIROFI interest in Internet of Things (IoT) Services Enablement is medium, and in particular high related to defining the relationship to geospatial Sensor web enablement standards, and possible integration/enhancements for these.

7.2.4 Applications/ Services Ecosystem & Delivery Framework

Applications/ Services Ecosystem & Delivery Framework has initially defined 9 generic enablers.

Applications/ Services Ecosystem & Delivery Framework	ENVIROFI Interest		2
	Release 1	Apps.USDL	3
		Apps.Repository	3
		Apps.Marketplace	3
		Apps.Registry	3
		Apps.RSS	2
		Apps.Mediator	3
		Apps.CompositionEditor	3
		Apps.CompositionExecution	2
	Release 2	Apps.Monitoring	2

Figure 7-4. ENVIROFI Interest in Applications/Services Ecosystem & Delivery Framework Enablers

The ENVIROFI interest in Applications/Services Ecosystem & Delivery Framework Enablers is medium to high, and in particular high related to defining the relationship to geospatial registries, catalogues and repositories as well as service composition and mediation.

7.2.5 Security

Security has initially defined 6 generic enablers.

Security	ENVIROFI Interest		3
	Release 1	Security.Security Monitoring	2
		Security.Context-based security & compliand	3
		Identity Management Generic Enabler	3
		Security.Privacy Generic Enabler	3
		Security.Data Handling Generic Enabler	2
		Security.Optional Security Enablers	2
	Release 2		

Figure 7-5. ENVIROFI Interest in Security Enablers

The ENVIROFI interest in Security is high, as this is an area where it is in particular expected that FI-WARE will provide the necessary solutions.

7.2.6 Interface to Networks and Devices (I2ND)

Interface to Networks and Devices (I2ND) has initially defined 4 generic enablers.

Interface to Networks and Devices (I2ND)	ENVIROFI Interest		
	Release 1	I2ND.CDI	1
		I2ND.CE	2
		I2ND.NetIC	1
		2ND.S3C	1
	Release 2		

Figure 7-6. ENVIROFI Interest in I2ND Enablers

The ENVIROFI interest in Interface to Networks and Devices (I2ND) is relatively lower, as this.is an area that is foreseen to be used as an underlying support area. ENVIROFI has, however, relevant requirements that will be put forward for this area.

7.2.7 Developers' Community and Tools

Developers' Community and Tools has initially defined 3 supporting tool areas.

Developers' Community and Tools	ENVIROFI Interest		3
	Release 1	FI-WARE IDE	3
		FI-WARE Catalogue Portal	3
	Release 2	FI-WARE Added Development Support tools	3

Figure 7-7. ENVIROFI Interest in Developers' Community and Tools Enablers

The ENVIROFI interest in the Developers' Community and Tools is high, as this is an area that will be important interfaces between the use case pilot development and the provisioning of the FI-WARE enablers.

7.3 ENVIROFI Priorities for FI-WARE Enablers

7.3.1 Overview

For the interaction between the Use Case projects and the FI-WARE project a system for the agile handling of requirements have been established, based on FusionForge. The ENVIROFI project has here[23] introduced the approach for structured agile requirements management as described in D4.1.1, using a leveled structure from **Themes** to **Epics** to **Features** to **User stories**. These might be derived from, or mapped to, use cases as outlined in D4.1.1.

Below we show the main issues that have been put forward from ENVIROFI to FI-WARE so far.

1. Geospatially enable the FI-WARE; that is assure FI-WARE architecture and services are locationally/geospatially aware and compatible to the available standards in the geospatial domain (including especially ISO TC211, CEN TC287 and OGC, at least at the conceptual level). Then we should be able to use quite a few of the GEs in Environmental UA applications.
    - Environmental Usage Area uses well-defined and standardized services for resource registry (catalogue of geospatial data and services). The solution is de-centralized and federated, so that we have world-wide catalogues. We need some clever way to assure the same resources are available on the FI-WARE marketplace with minimal effort. See ENVIROFI.Epic.DeliveryFramework.ResourceRegistryService
    - At security level: ENVIROFI.Feature.Security.GeospatialConstraints
    - Events: e.g. ENVIROFI.Feature.Unknown.GeospatialAlerts. Please note that "Observations" are also defined as events in OGC Sensor Web Enablement.
    - Location based services: some of the GEs in Data/Context seem predestined for this. But we also need to contact all users within a given area, even if our app is not active (saves battery, more reliable); contact everyone within a given area, even if they aren't using our apps yet (for important warnings)

2. Clarify the relationship/overlaps between IoT Enablement and OGC Sensor Web Enablement. (To which extent) should SWE be endorsed by FI-WARE?
    - Do other UC projects need any of these: ENVIROFI.Epic.Data.ObservationService, ENVIROFI.Epic.Data.ObservationReportingClient, ENVIROFI.Epic.Data.ObservationsManagementServices?
    - SWE could be part of the new "geospatial" chapter, or merged into IoT, or in Data/Context.

3. Same as above for uncertainty
    - Withouth uncertainty-related information, all of our predictions are quite useless.
    - Also see the ENVIROFI.Epic.Data.EnvironmentalDataUncertaintyManagementService - this could help with data sources that do not provide uncertainty (yet)

4. Visualization
    - Geospatial "Viewing" services, e.g. web map service are used in huge number of applications. What we miss is the contextual viewing service, which will hide the

[23] https://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/Unclassified_Themes/Epics/Features_Backlog#ENVIROFI

information user is not interested in.

(See ENVIROFI.Epic.Data.ContextAwareViewService)

- Augmented Reality is becoming the technology of choice for visualization of geospatial information on mobile devices. State of the art AR viewers do not fulfill our needs.

  (See ENVIROFI.Epic.DeliveryFramework.EnvironmentalARFramework)

- Also converge with virtual reality.

5. Semantics
   - Above all the possibility to easily merge semantically annotated data from two sources (each source uses own data model/semantic description)

ENVIROFI Candidates for open calls:

- ENVIROFI.Epic.Data.ContextAwareMapService
- ENVIROFI.Epic.DeliveryFramework.EnvironmentalARFramework
- ENVIROFI.Feature.IoT.MobileSensorAbstraction
- ENVIROFI.Feature.Security.NFC_Auth
- ENVIROFI.Feature.Security.GeospatialConstraints

7.3.2 Themes

ENVIROFI uses "themes" to explain the abstract/broad ideas, and to set the context for epics. Themes are therefore very ENVIROFI-specific; the request to FI-WARE and AB is only to think of the ways how these themes fit in the big picture and their own work.

- ENVIROFI.Theme.ModelWeb
- ENVIROFI.Theme.ObservationWeb
- ENVIROFI.Theme.SDI - Spatial Data Infrastructures
- ENVIROFI.Theme.VGI - Volunteered Geographic Information
- ENVIROFI.Theme.SemanticWeb

7.3.3 Epics

ENVIROFI uses "epics" to instantiate the particular items required by one or more of the themes.

- ENVIROFI.Epic.Data.EnvironmentalFusionServices
- ENVIROFI.Epic.Data.ObservationService
- ENVIROFI.Epic.Data.ObservationReportingClient
- ENVIROFI.Epic.Data.LinkedOpenEnvironmentalDataServices
- ENVIROFI.Epic.Data.EnvironmentalDataUncertaintyManagementService
- ENVIROFI.Epic.Data.ObservationsManagementServices
- ENVIROFI.Epic.Data.EnvironmentalAlertServices

- ENVIROFI.Epic.Data.ContextAwareViewService
- ENVIROFI.Epic.Data.ObservationTrustManagementService
- ENVIROFI.Epic.DeliveryFramework.EnvironmentalARFramework
- ENVIROFI.Epic.Data.EnvironmentalResourceCatalogues
- New: ENVIROFI.Epic.DeliveryFramework.ResourceRegistryService.

7.3.4 Features

ENVIROFI uses features to clearly explain which benefit ENVIROFI expects from FI-WARE. These benefits should always be in the context of themes and epics listed above.

- ENVIROFI.Feature.Cloud.ObjectStorage.ObservationStorageInTheCloud
- ENVIROFI.Feature.DataManagement.UncertaintyHandling
- ENVIROFI.Feature.DataManagement.MobileGeoLocation
- ENVIROFI.Feature.DeliveryFramework.DataAndServicePayment
- ENVIROFI.Feature.DeliveryFramework.AcceptLicence
- ENVIROFI.Feature.IoT.MobileSensorAbstraction
- ENVIROFI.Feature.Security.Privacy.PrivacyShield
- ENVIROFI.Feature.Security.NFC_Auth
- ENVIROFI.Feature.Security.GeospatialConstraints
- ENVIROFI.Feature.Unknown.GeospatialAlerts

These inputs are currently being evaluated by the FI-WARE project and will a subject for further dialogue during the planning of extensions and open calls by the FI-WARE project.

7.4 Hybrid SPARQL-SQL Information Model for Data Fusion

7.4.1 Overview

An interesting exemplar information model exists from the European research project TRIDEC (Wächter et al, 2011). In TRIDEC the fusion and modelling architecture of the European research project Sensors Anywhere (SANY) (Middleton (ed.), 2010) has been extended, focusing on the challenges associated with handling very large scale real-time data from heterogeneous sources such as sensor networks and Web 2.0 sites. Practical experience has been taken on board from real-world deployed natural disaster management systems, including the German Indonesian Tsunami Early Warning System (GITEWS) (Münch et al, 2011) and Distant Early Warning System (DEWS) (Esbri et al, 2010) projects.

The TRIDEC approach is to implement a high performance knowledge-based data fusion framework built upon OGC and W3C standards. These standards support semantic interoperability, allowing metadata driven automation when integrating self-described data sources. Each data fusion and data mining process works at its own explicit semantic level, inspired by the de-facto Joint Directors of Laboratories (JDL) (Lampert, 2009) data fusion information model. To ensure both scalability and high messaging performance a hybrid event-driven architecture is adopted, exploiting the best of the service-oriented and event-driven architecture paradigms.

The types of data source available in TRIDEC include seismic sensor networks, tide gauges, rig sensor systems, camera feeds and web 2.0 sites such as twitter and You Tube. Data is published to a multi-bus messaging middleware using a variety of text and binary encoded formats, coupled with a SWE 1.0 metadata document that self-describes each data source.

7.4.2 Multi-level Data Fusion Approach to Heterogeneous Domain Information Models

A number of high performance database feeder services are setup to subscribe to each data source, reading in SWE 1.0 metadata documents published by each data source and transforming it into a SWE 2.0 encoded RDF metadata graph. Published data payloads are stored either directly as triples, under a SWE 2.0 values RDF node, or indirectly in a relational database (e.g. measurement time series) or file system (e.g. JPEG image data, ASCII GRID simulations). The RDF metadata includes triples that semantically describe each SQL data table, allowing clients to automatically construct SQL queries to access cached and processed datasets.

A set of SQL tables is created per SWE observation data array, allowing the RDF metadata to be inserted once and data from future real-time measurement samples to be efficiently inserted directly into the SQL tables. This approach ensures real-time data upload software can exploit high performance SQL database endpoints, avoiding overuse of triple store insert and query endpoint bottlenecks.

Figure 7-8 and Figure 7-9 show examples of both the SWE 2.0 RDF metadata and data graphs, and the SQL tables they describe. Work by the OGC on a set of approved OGC RDF OWL classes is still at an early stage. In TRIDEC the OGC's XML schema striping (W3C, 2004) is exploited to help transform SWE XML to SWE RDF without the need to explicitly link to OGC ontology classes; this is a practical approach since it allows any valid OGC XML to be transformed, no matter how complex.

RDF graph - metadata description

```
ns:dataset1 it-innov:hasObservation ns:meta1
  ns:meta1 rdf:type om:OM_Observation
  ns:meta1 gml:description <observation description>
  ns:meta1 gml:name <observation id>
  ns:meta1 om:type ns:meta2
    ns:meta2 xlink:href "http://www.opengis.net/def/observationType/OGC-OM/2.0/OM_ComplexObservation"
    ns:meta2 xlink:role "http://purl.oclc.org/NET/ssnx/ssn#Observation"
  ns:meta1 gml:boundedBy ns:meta3
    ns:meta3 rdf:type gml:Envelope
    ns:meta3 srsName "http://www.opengis.net/def/crs/EPSG/0/4326"
    ns:meta3 axisLabels "lat lon"
    ns:meta3 uomLabels "deg deg"
    ns:meta3 srsDimension "2"
    ns:meta3 gml:lowerCorner "1.23463 1.86753"
    ns:meta3 gml:upperCorner "53.22334 53.33424"
  ns:meta1 om:phenomenonTime ns:meta4
    ns:meta4 rdf:type gml:TimePeriod
    ns:meta4 gml:id "sample-time"
    ns:meta4 gml:frame "http://www.opengis.net/def/trs/OGC/0/GPS"
    ns:meta4 gml:beginPosition <start time>
    ns:meta4 gml:endPosition <end time>
  ns:meta1 om:resultTime ns:meta5
    ns:meta5 xlink:href <upload time>
  ns:meta1 om:procedure ns:meta6
    ns:meta6 xlink:href <O&M procedure URL>
    ns:meta6 xlink:arcrole "http://purl.oclc.org/NET/ssnx/ssn#Sensor"
  ns:meta1 om:observedProperty ns:meta7
    ns:meta7 xlink:href <O&M observed property URL>
    ns:meta7 xlink:arcrole "http://purl.oclc.org/NET/ssnx/ssn#observedProperty"
  ns:meta1 om:featureOfInterest ns:meta8
    ns:meta8 xlink:href <O&M feature of interest URL>
    ns:meta8 xlink:arcrole "http://purl.oclc.org/NET/ssnx/ssn#featureOfInterest"
  ns:meta1 om:resultns:meta9
    ns:meta9 rdf:type swe:DataArray
    ns:meta9 xsi:type "swe:DataArrayPropertyType"
    ns:meta9 xlink:arcrole "http://purl.oclc.org/NET/ssnx/ssn#observationResult"

    ... swe:elementCount, swe:elementType, swe:encoding ...

  ns:meta1 swe:values ns:data1
```

Figure 7-8. TRIDEC SWE 2.0 metadata graph describing an observation from a data source

RDF graph - data description

```
ns:meta1 swe:values ns:data1
  ns:data1 rdf:type it-innov:SQLTable
  ns:data1 xlink:arcrole "http://purl.oclc.org/NET/ssnx/ssn#ObservationValue"
  ns:data1 it-innov:hasDefinition <O&M procedure URL>
  ns:data1 it-innov:hasHost <SQL host IP address>
  ns:data1 it-innov:hasPort <SQL host IP address>
  ns:data1 it-innov:hasConnector "jdbc:mysql"
  ns:data1 it-innov:hasDriver "com.mysql.jdbc.Driver"
  ns:data1 it-innov:hasCatalogue <SQL database name>
  ns:data1 it-innov:hasTableName <table ID>
  ns:data1 it-innov:hasExampleQuery <SQL query to get all data>
  ns:data1 it-innov:hasD2RQMapping <d2rq database map link>
  ns:data1 it-innov:hasColumn ns:data2
    ns:data2 tdf:type it-innov:SQLColumn
    ns:data2 it-innov:hasDefinition it-innov:ID
    ns:data2 it-innov:hasUnit ""
    ns:data2 it-innov:hasName "p_id"
    ns:data2 it-innov:hasType "int"
    ns:data2 it-innov:hasColumn [#]
  ns:data1 it-innov:hasColumn ns:data3
    ns:data3 tdf:type it-innov:SQLColumn
    ns:data3 it-innov:hasDefinition <http://www.opengis.net/def/property/OGC/
0/SamplingTime>
    ns:data3 it-innov:hasUnit "s"
    ns:data3 it-innov:hasName "time"
    ns:data3 it-innov:hasType "int"
  ns:data1 it-innov:hasColumn ns:data4
    ns:data4 tdf:type it-innov:SQLColumn
    ns:data4 it-innov:hasDefinition tde:MDBit
    ns:data4 it-innov:hasUnit "m"
    ns:data4 it-innov:hasName "mdbit"
    ns:data4 it-innov:hasType "float"
  ...
```

SQL table structure - data values

p_id	time	mdbit	... column per measurement
1	3234234	529	
2	3234294	543	
3	3234354	785	
4	3234414	976	

... row per sample

Figure 7-9. TRIDEC SQL table of measurement values & RDF graph describing that table

This hybrid SPARQL / SQL storage solution allows clients to query directly via a W3C interface (SPARQL + SQL query for W3C linked data users). With the addition of a TRIDEC SOS frontend an OGC SOS interface (XML request/response for OGC geospatial users) is also supported.

Each data fusion process is hosted by an OGC SPS 2.0 and operates at an explicit JDL-style semantic level, such as pre-processing, feature extraction/object refinement or situation assessment. Fusion processes store their intermediate and final result data using the hybrid SPARQL / SQL storage solution, exploiting database locking mechanisms to support concurrent access to a shared 'data workspace'. Figure X-3 shows the logical information flow between data sources and fusion processes in TRIDEC.

As the volume of cached data and fusion results grow multiple instances of databases and database feeders services can be created, and message routing changed to balance the data throughput load.

7.4.3 Domain Vocabulary Mapping and the W3C Semantic Sensor Network Ontology

To overcome inter-domain vocabulary mapping issues TRIDEC domain concepts (e.g. observed property types) are referenced by explicit URL's pointing to domain OWL ontologies. This approach allows the use of W3C semantic web tooling (Bizer et al, 2009) to infer mappings between identical measurement concepts and other useful domain relationships.

The SQL database can itself be directly exposed as a linked data repository via semantic web tools like D2R (Bizer and Cyganiak, 2006). A D2RQ mapping link is included in the SQL table metadata graph to allow this. Supplying semantics directly in RDF graphs avoids the need for local domain profiles and mapping tables. For high performance access to data, use of direct SQL endpoints is still preferable however.

A number of OGC and W3C working groups have looked at semantic interoperability issues between different sensor measurement domains. In the W3C community the semantic sensor network ontology

(SSNO) (Lefort, Henson and Taylor, 2011) has been developed as a high level bridge between OGC schema concepts and W3C ontologies. In TRIDEC these high level concepts are linked to using the attributes xlink:role and xlink:arcrole as recommended by W3C. The OGC schema themselves provide protocols and syntax for geospatial concepts but do not directly support domain vocabulary, instead expecting users to publish using the domain measurement types they are familiar with.

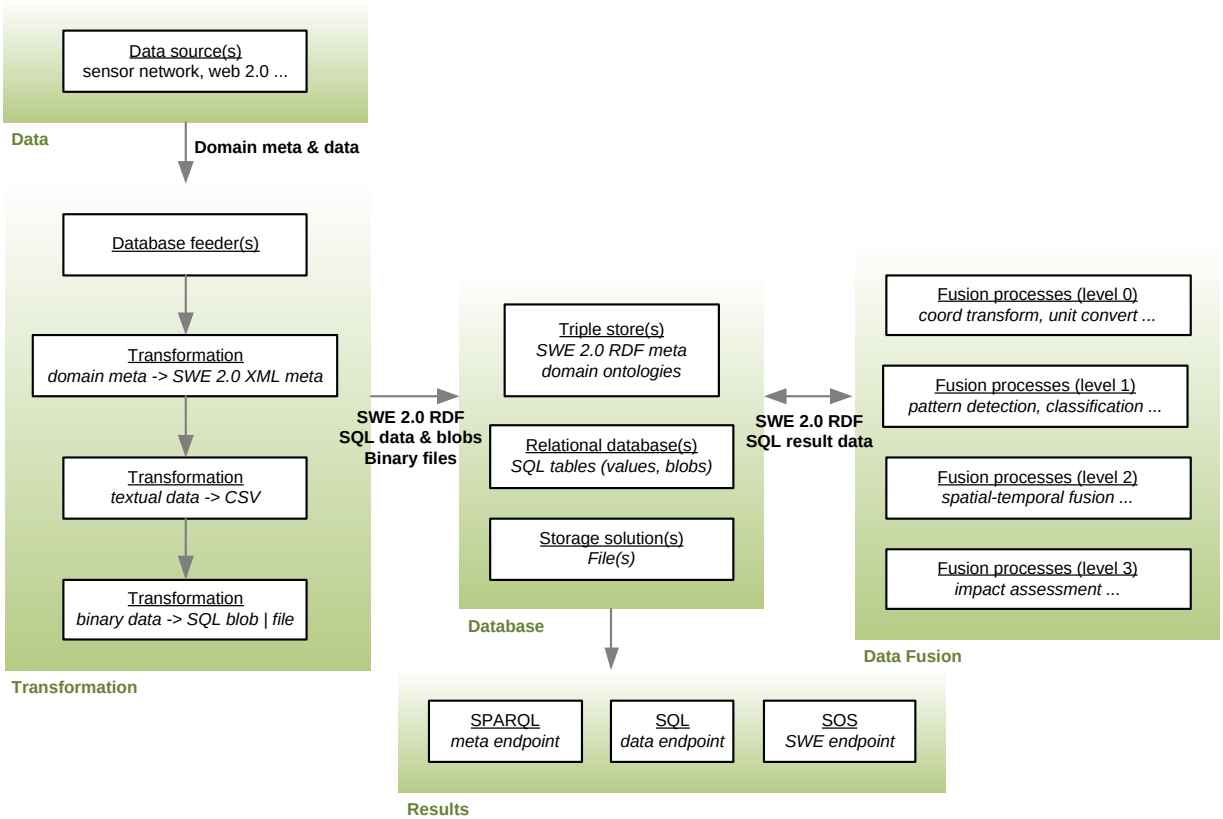

Figure 7-10. TRIDEC logical information flow (data sources & fusion at multiple JDL levels)

7.4.4 Application of Exemplar SPARQL/SQL Approach within ENVIROFI

One of the key concepts when exposing sensor data as linked data is to ensure the data can be directly referenceable via concrete URL's. This is challenging for large data sets, as in TRIDEC we have found that the performance of triple stores becomes inadequate for real-time access to datasets with more than about 100,000 samples. In TRIDEC the observation data array records are directly referenceable, but the individual measurement data values are accessed indirectly via a SQL query. Directly referenceable URL's to measurement data in a SQL database table is under experimentation, achieved using a D2R server approach.

In ENVIROFI we plan to experiment with the results from the TRIDEC SPARQL/SQL information model and create a fusion mediator, providing a single endpoint that clients can use to execute W3C SPARQL queries across federated fusion result sets held in different databases. This mediated approach will remove the need to execute multiple SPARQL and SQL queries and manually fuse the results. The mediator will likely also support enhanced SPARQL filter operations (e.g. GeoSPARQL, OWLIM enhancements), allowing use of spatial and temporal filters, and support the powerful SQL filter operations.

In ENVIROFI we will also follow the de-facto standard JDL information model for our data fusion service, creating data fusion processes that operate at different semantic levels. These will be controlled by SWE SPS services, providing a service interface familiar to the geospatial community.

To cope with fusion of heterogeneous data sources we will implement a pipeline pattern, transforming data from a variety of domain specific formats into a combination of SWE XML metadata & text/binary data. Raw data will thus be fed into SPARQL/SQL database(s) which is then used as a kind of 'shared database workspace' for data fusion processes to enrich the data and create derived fusion result sets.

To record and use uncertainty information in ENVIROFI we will setup an uncertainty annotation service. This will exploit the linked data access to raw and processed data to store uncertainty annotations in separate graphs / databases, linking them explicitly to the original data & result set URL. This approach will be used to store uncertainty (e.g. SWE quality data[24], UncertML records[25], results of the UncertWeb project[26]), provenance (e.g. SensorML, W3C provenance ontology (W3C, 2011)) and trust (e.g. multiple user-specific trust models in specific data sources).

[24] http://www.opengeospatial.org/projects/groups/sensorweb

[25] http://www.uncertml.org/

[26] http://www.uncertweb.org

8 Conclusions

This deliverable describes the current understanding of the ENVIROFI Environmental Architecture following the viewpoint approach of the ISO Reference Model for Open Distributed Processing. In its current version D4.2 it draws upon relevant results of previous European research projects and their approach to apply international standards of the geospatial domain for environmental applications.

This approach has been taken as in the environmental domain such architectural work cannot start from scratch. On the contrary, there are large-scale international activities such as GEOSS, INSPIRE and SEIS that were set-up in the last years which all built upon standards and standard profiles of the International Organization for Standardization (ISO), the Open Geospatial Consortium, the OASIS (Organization for the Advancement of Structured Information Standards), the Object Management Group (OMG) and the W3C (World Wide Web Consortium), just to denote the most important ones.

Furthermore, there have been numerous European research projects in the last years that developed corresponding geospatial service-oriented architectures, design patterns and solution components for the environmental domain, and, even more, influenced the development of international standards.

The ENVIROFI Environmental Architecture defines an enabler as “a software component in an implementation architecture with a well-defined interface that fulfils a given set of functional, informational and qualitative requirements”. As a result implementation architectures in FI-PPP are expressed in terms of an aggregation and collaboration of enablers.

Now, in the context of the FI-PPP, this work has to be mapped to the world of generic and specific enablers comprising the development and run-time platform of the Future Internet. Due to the importance of the geospatial characteristics in the environmental domain, the specific enablers of ENVIROFI are classified into geospatial enablers based upon geospatial services and information models, and environmental enablers that are tailored to the various environmental disciplines.

Following the agile analysis and design approach of ENVIROFI and the whole FI-PPP project cluster, this present version of the ENVIROFI Environmental Architecture specification shall be considered as a two-side snapshot of the architectural analysis after 1 year of the FI-PPP.

On the one hand, it reflects the knowledge about architectural requirements stemming from the ENVIROFI pilots. As a result, ENVIROFI aims at a multi-style architecture based upon standard services and information models as geospatial enabler components. On the other hand, it recognizes the envisaged offer of the FI-WARE core platform but cannot assess them for usability in the ENVIROFI pilots. Hence, the prioritization and the mapping of the environmental enablers of ENVIROFI to the generic enablers of FI-WARE might be updated and, consequently, provided in an updated version of this deliverable.

Furthermore, the next iteration will define the architectural styles that environmental application requires in terms of service-oriented design patterns applied to environmental, geospatial and generic enablers of the Future Internet.

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Table 9-1. References

10 Annex A - TR 15449-4

This annex contains the table of contents for the emerging CEN/TC287 TR 15449-4 report - Geospatial standards – Infrastructures.

Input to TR 15449-4 has been derived from initial ENVIROFI work in D4.1.1 and further input from ENVIROFI partners, using a model based approach with RM-ODP viewpoints.

The Part 4 of TR 15449 describes a service-centric view of a Spatial Data Infrastructure (SDI). The Service Centric view addresses the concepts of service specifications, the methodology for developing service specifications through the application of the relevant International Standards, and the content of such service specifications described from the perspective of the five Reference Model of Open Distributed Processing (RM-ODP) viewpoints. The enterprise viewpoint addresses service aspects from an organisational, business and user perspective. The computational viewpoint addresses service aspects from a system architect perspective. The information viewpoint addresses service aspects from a geospatial information expert perspective. The engineering viewpoint addresses service aspects from a system designer perspective. The technology viewpoint addresses service aspects from a system builder and implementer perspective.

The draft technical report itself is provided as a confidential annex, as the report is in progress to be published through the regular CEN/TC287 publication channels.

We will be harmonising the results in ENVIROFI with the suggested approach for TR 15449, and also provide ENVIROFI results as examples in a future revision of this report.

TR 15449-4 Contents

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