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Architectures and Standards for Spatial Data Infrastructures and Digital Government

European Union Location Framework Guidelines

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ELISE

Enabling digital government through geospatial & location intelligence

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Abstract

This document provides an overview of the architecture(s) and standards for Spatial Data Infrastructures (SDI) and Digital Government. The document describes the different viewpoints according to the Reference Model for Open and Distributed Processing (RM-ODP) which is often used in both the SDI and e-Government worlds: the enterprise viewpoint, the engineering viewpoint, the information viewpoint, the computational viewpoint and the technological viewpoint. The document not only describes these viewpoints with regard to SDI and e-Government implementations, but also how the architecture(s) and standards of SDI and e-Government relate. It indicates which standards and tools can be used and provides examples of implementations in different areas, such as process modelling, metadata, data and services. In addition, the annex provides an overview of the most commonly used standards and technologies for SDI and e-Government.

Executive Summary

This report describes how the Spatial Data Infrastructure (SDI) and e-Government worlds relate to each other from the perspective of their architectures and standards. This work aims to improve their integration and support a location-enabled e-Government environment of relevance to the European Interoperability Framework (EIF) and other activities currently being performed in the Interoperability Solutions for public Administrations, businesses and citizens (ISA^2) Programme. This is especially relevant in the context of the current trends in e-Government towards 'Digital Government', as well as the 'Digital Transformation of Government', which is influenced by recent technological trends such as the Application Programming Interface (API) movement, Big Data (and Big Data analytics), blockchain and ledger technologies, the Internet of Things, amongst others. The report focuses on e-Government processes, the architecture(s) for SDIs and e-Government, the semantic assets they build upon (metadata and data) and the services that support and steer the processes. An extensive annex lists most of the major e-Government and geospatial standards. In the latest version of this report, the latest technology trends have been integrated to clarify whether and how they influence the existing SDI and e-Government architectures and standards.

The report aims to provide an overview of the different aspects of standardisation in both the e-Government and SDI worlds, and how they inter-relate (or not). In order to do so, the Reference Model for Open and Distributed Processing (RM-ODP)[1] with the five perspectives – the enterprise viewpoint, the engineering viewpoint, the information viewpoint, the computational viewpoint and the technical viewpoint - is used to describe these architectures and standards, and where possible to provide examples of implementations. It should be noted that the RM-ODP model is not only used in the geospatial world, for example it is the basis for the OGC and ISO 19100 series of standards, which are in turn used as a basis for the specifications used for Directive 2007/2/EC, establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) (Biancalana *et al*., 2010), but are also used in the e Government world, for example in the Standards and Architectures for eGovernment Applications document of the German e-Government initiative SAGA (SAGA, 2008).[2]

As part of the ISA^2 Programme's European Location Interoperability Solutions for e-Government (ELISE) Action, the European Union Location Framework (EULF) addresses the integration of location information in e-Government and the importance of interoperability when doing so. The technologies and standards used in both e-Government and geospatial communities are key considerations. Developers, managers and users of SDIs need to know if what they do in a particular context is in line with related activities in e-Government, and vice versa e-Government managers need to understand the specific standards of the geospatial world and how they fit in their own architecture.

In the context of SDI and e-Government developments, at least seven Standardisation Development Organisations (SDO) play a central role: INSPIRE (through its Maintenance Implementation Group, MIG), ISO/TC 211 and the Open Geospatial Consortium (OGC) for the geospatial domain; the ISA^2 Programme, W3C and the Organisation for the Advancement of Structured Information Standards, (OASIS) for the general ICT and e-Government domain, and the Object Management Group (OMG) for the modelling domain. It is good to observe that many of these SDOs already work together intensively: e.g. most of the OGC standards are based upon generic Internet standards. In the context of the ISA^2 Programme, specific attention is paid to the geospatial domain and its standards, while the geospatial community, especially through INSPIRE, is taking into account developments that take place in the ISA^2 Programme.

Enterprise viewpoint – e-Government developments mostly start from the business process perspective for which they provide services to support the interactions between governments (G2G) and between governments, citizens (G2C) and businesses (G2B). Analysing e-Government activities from the business process perspective allows us not only to understand, manage and improve the information flows and the many G2G, G2B and G2C interactions that take place, but also to identify the places where location information and location-based services can add value to the process. While the development of SDIs usually focus on the infrastructure *per se* - i.e. the harmonisation of geospatial data, the set-up of web services and the documentation of both data and services - the business process perspective shifts the focus more to the uptake of the components of the infrastructure by the users in those business processes. This user-centricity is crucial for making SDI and INSPIRE, in particular, successful. ***It is advisable for the geospatial community to take part in the systematic modelling of e-Government processes to help identifying where and how SDI components***

[1] http://www.rm-odp.net/

[2] RM-ODP, is also known as ITU-T Rec. X.901-X.904 and ISO/IEC 10746. The standard is a joint effort by the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the Telecommunication Standardization Sector (ITU-T).

such as geospatial web services can improve such processes. Many standards and tools exist on which the geospatial community can rely in order to map and manage processes and to automate the execution of services that support them.

Engineering viewpoint – e-Government architectures are component-based and utilise Service Oriented Architecture (SOA). SDIs and INSPIRE follow a similar approach. Both architectures have a data/content tier, a service tier and an application tier. It can be argued that e-Government pays more attention to the application tier (different user interfaces for accessing services), while SDIs and INSPIRE focus more on the geoportal application as the access point for the (publishing)-searching-finding-binding of geospatial data through network services. The fact that e-Government and SDI architectures are quite similar, means that e-Government architectures can easily integrate location-based components such as INSPIRE Network Services (the collection of web services defined by the Directive to share metadata and data), and vice versa. Furthermore, it allows SDI and INSPIRE components to be mapped into the European Interoperability Reference Architecture (EIRA) through the European Interoperability Cartography (EIC). The frameworks, tools and standards for describing the architectures are quite similar. For example, the RM-ODP usually used in the geospatial world and the EIRA (based on TOGAF) have very similar views to describe the ICT architecture and its components, and several frameworks and standards are available to describe them. Over the past few years, SDIs and e-Government initiatives have been focusing more and more on opening up information and infrastructural components through APIs. This is gradually becoming an additional layer in the SDI architecture but, perhaps more importantly, the likely 'building site' for location-enabled e-Government services.

Information viewpoint – The geospatial community has its own metadata standards, while the semantic standards have mainly be developed through ISO/TC 211, i.e. the so called ISO 19100 series of standards (which was also the basis for the thematic data models of INSPIRE). The geospatial community has a rich tradition in creating (theme specific) spatial data models that encapsulate semantic aspects. The general ICT and e-Government communities have also developed metadata standards and other semantic assets such as controlled vocabularies. Many of the semantic standards for e-Government have been developed using basic standards from, for example, W3C. They cover data and metadata: the Data Catalogue Vocabulary (DCAT) has been extended to DCAT-AP to address specific European requirements for exchanging information from catalogues, while the draft GeoDCAT-AP profile has, in turn, built further on DCAT-AP to cover specific requirements from the geospatial and INSPIRE communities (by those communities). Also the Asset Description Metadata Schema (ADMS) has been used, for example, to document INSPIRE assets such as tools and code lists. Other work has explored the transformation between INSPIRE data specifications such as 'addresses', specific national profiles and the ISA Core Location Vocabulary. All this work has shown that the exchange of assets between the geospatial and e-Government world is not only possible but also required. Such exchange opens up new opportunities and will make the integration of location information within e-Government feasible and easier. In general, there is interest from the geospatial communities within Member States to provide their data and metadata not only through INSPIRE services, but also as Linked Data to enhance their exposure on the Web and to open up new ways of using them. In this sense, the application of e-Government semantic standards is complementary to the application of geospatial standards and the INSPIRE approach. The way geospatial data are published and used online (linking data resources) has also notably changed over recent years. The efforts of W3C and OGC working together on their Spatial Data on the Web initiative should be noted in this context.

Computational viewpoint – e-Government services delivered to citizens, business and government bodies become very powerful if they support the many business processes and their interactions. Service delivery can be organised in a flexible way, i.e. the different sub-processes / activities can be applied in several services and delivered by various organisations. There are different models to steer this process and their sub-processes: from central steering to relaying to a sub-contractor. The example provided shows that this process-oriented approach has already been applied in the geospatial community, as well. Indeed, in the context of the OGC Interoperability Programme (OWS-8, OGC Web Services Initiative Phase 8) work has been done to 'automate' and orchestrate complex (spatial) data flows through OGC Web Services. This has been done not only for (secure) access to the data, but also for automated semantic data harmonisation using a mediation service. This is going clearly beyond the 'simple' set-up of OGC services to be used within a process by a single application (e.g. WMS), as its focus is on the organisation and automation of the process itself. The example shows which direction to take: i.e. to analyse existing, and design new, processes for e-Government in which geospatial data and processing are embedded. APIs allow us to develop new and innovative applications more efficiently for citizens, businesses and governments alike. They are a factor that facilitates the integration of the geospatial and e-Government worlds and are a potential driver for the Digital Transformation of Government.

Technology viewpoint –consists of a comprehensive overview of the relevant standards that are frequently applied in SDI and e-Government implementations. The overview given in the Annex of this report is certainly not exhaustive and ideally might become available as an online repository of standards, or become part of the standards repository planned by the ISA² Programme. The list is in continuous development in the sense that the respective standardisation bodies alter, add or drop standards. The list is useful though that it provides an overview, grouped in different categories: standards for business process modelling; standards for data, metadata and data exchange; standards for secure access; standards for licensing and e-business; and standards for web services. In total, 48 standards from different standardisations are briefly described.

1 Introduction

1.1 The European Union Location Framework

The European Union Location Framework (EULF) aims to maximise the potential of the vast amount of money spent on location-related information and services by governments across Europe by promoting a best practice approach for cross-sector and cross-border sharing and use of this information, based on user needs and priorities, and targeting actions that will deliver efficiencies, help improve digital public services, and contribute to job creation and growth. The vision for the EULF can be summarised as follows: *"More effective services, savings in time and money, and increased growth and employment will result from adopting a coherent European framework of guidance and actions to foster cross-sector and cross-border interoperability and use of location information in e-Government, building on INSPIRE".*

The EULF was established under the European Commission's Interoperability Solutions for European Public Administrations (ISA) Programme, and now forms part of the European Location Interoperability Solutions for e-Government (ELISE) Action in the successor ISA[2] programme[3]. EULF guidance and actions are targeted at improving interoperability and use of location information in e-Government services, based on five focus areas:

Policy and strategy alignment: a consistent EU and Member State policy and legislative approach where location information plays a significant role.

Digital government integration: making location a key enabler in G2B, G2C and G2G e-government processes and systems.

Standardisation and reuse: adoption of recognised geospatial and location-based standards and technologies, enabling interoperability and reuse.

Return on investment: ensuring funding of activities involving location information is value for money, and taking action concerning this information to stimulate innovation and growth.

Governance, partnerships and capabilities: effective decision making, collaboration, knowledge and skills, related to the supply and use of location information in the context of digital government.

EULF outputs include:

- '**EULF Strategic Vision**' - a shared vision and rationale for a European Union Location Framework, defining the scope, governance and implementation approach;
- '**Assessment of the conditions for an EULF**' - an assessment of the state of play in the different focus areas of the EULF and the need for EULF action in these areas;
- '**EULF Blueprint**' – recommendations and guidance in the five EULF focus areas and role-based views for key stakeholder groups;
- '**EULF Guidelines**' – Detailed guidance on key topics introduced in the EULF Blueprint. This document, '**EULF Architectures and Standards for SDIs and e-Government'** is one of those documents.
- '**EULF References**' - inventories, links and supplementary information related to the EULF;
- **'EULF Studies'** - assess the feasibility of EU action in various policy areas, involving the sharing and reuse of location information;

3 https://ec.europa.eu/isa2/home_en

- **'EULF Pilots'** - create location interoperability solutions in various policy areas (e.g. transport, marine and energy) applying and informing EULF best practices in solving real-world problems.

1.2 Objectives, scope and target audience

1.2.1 Objectives

This document fulfils a need identified by Member States during the work conducted on the Assessment of the Conditions for the EULF. Work is centred around the concepts associated with Spatial Data Infrastructures (SDI), including the specific developments in Member States supporting the implementation of the INSPIRE Directive. An SDI can be considered as an activity and set of technical resources that provide the technological, semantic, organisational and legal structure that enable the discovery, sharing, and use of geospatial data/information. An SDI refers to the collection of technological and non-technological components oriented towards facilitating and coordinating spatial data-sharing. Examples of technological components are metadata, standards, access networks and spatial datasets, while funding, policies and governance are seen as its main organisational components. They engage with interoperability at all levels of the European Interoperability Framework (EIF) and have a strong focus on data, making them a pertinent example in the context of the Digital Transformation of Government, as defined by Zhang *et al*. (2014), who indicate a need to consider "…fundamental changes in the way how public organizations are structured and operate, how public services are delivered, how policies are developed, implemented, and evaluated, as well as how citizens engage in democratic processes resulting from the introduction of technologies". The document, aims to contribute to the evolution of both SDIs and the Digital Transformation of Government involving geospatial data, technologies and thinking, especially from the perspective technical perspective of interoperability and integration.

The document has the following specific objectives:

1. To better understand the business processes that steer e-Government activities;
2. To describe the overall architecture for SDIs and e-Government;
3. To provide a better insight in the different e-Government standards that might be important for SDI development;
4. To clarify the relationship between standards for SDIs and standards for e-Government;
5. To understand and describe how recent technological developments are influencing architectures and standards for SDI and e-Government; and
6. To contribute in more general terms to the improvement of the interoperability, reusability, openness and scalability of governmental ICT solutions to be used by citizens, businesses and governments themselves.

1.2.2 Scope

This report describes how the SDI and e-Government worlds relate to each other regarding their architectures and standards, in order to improve their integration, enabling a location-enabled e-Government environment. Therefore, it focuses on e-Government processes, the architecture(s) for SDIs and e-Government, the semantic assets they build upon (metadata and data) and the services and technologies that support and steer the processes. The report provides:

- Insight into the landscape of standardisation of location information and services, its actors and the standardisation processes;
- Insight into the relevant standards, technologies and tools;
- Some concrete examples of implementations of the standards and tools, alongside summaries of pilot studies;
- References to sources for further reading.

The report does not discuss all the standards and tools in detail. The aim is, rather, to provide the overall picture and to provide links for further reading. Also, the report is not developed in the form of guidelines: there are no recommendations or 'to-do's'. In addition, the report does not repeat the standards for SDIs, as such, since this is the topic of other reports such as CEN/TR 15449 (CEN/TC 287, 2012; CEN/TC 287, 2011b; CEN/TC 287, 2011a) which provides a detailed overview of standards for SDIs. Finally, it should be stressed that the e-Government world is, just like the geospatial or SDI world, in continuous development. With the emerging topic of Digital Transformation of Government, this is even more the case. Therefore, it is worthwhile consulting regularly the references provided throughout the text and in the reference section (Section 7).

1.2.3 Target audience

The report is designed for use within public sector organisations by decision makers in the fields of information technology and e-Government; ICT managers and architects; developers of e-Government services and applications; developers of SDI/INSPIRE components; and more broadly by technicians and managers within public administrations.

The report is intended to support these actors who are responsible for the design of SDI and e-Government systems and services, and particularly for the integration of location information and location enabled services in e-Government processes.

1.2.4 Other related documents

The EULF Blueprint provides recommendations in five focus areas, aimed at improving the use of location information in e-Government processes and services. It is supplemented by a series of detailed guidance documents, including this *"Architectures and Standards for SDIs and Digital Transformation of Government"*. Other guidance documents include:

- Public Procurement of Geospatial Technologies
- Guidelines for public administrations on location privacy
- Design of Location Enabled e-Government Services

All documents are available on the ELISE website, https://ec.europa.eu/isa2/actions/elise_en and on JoinUp https://joinup.ec.europa.eu/collection/elise-european-location-interoperability-solutions-e-government/about.

1.2.5 Background and history of this document

The origin of this document goes back to work originally performed within CEN/TC 287, the European Standardization body for Geographic Information. Between 2010 and 2013 a multi-part document (5) describing the standards for SDI's was elaborated by the CEN/TC 287 Member States: CEN/TR 15449.

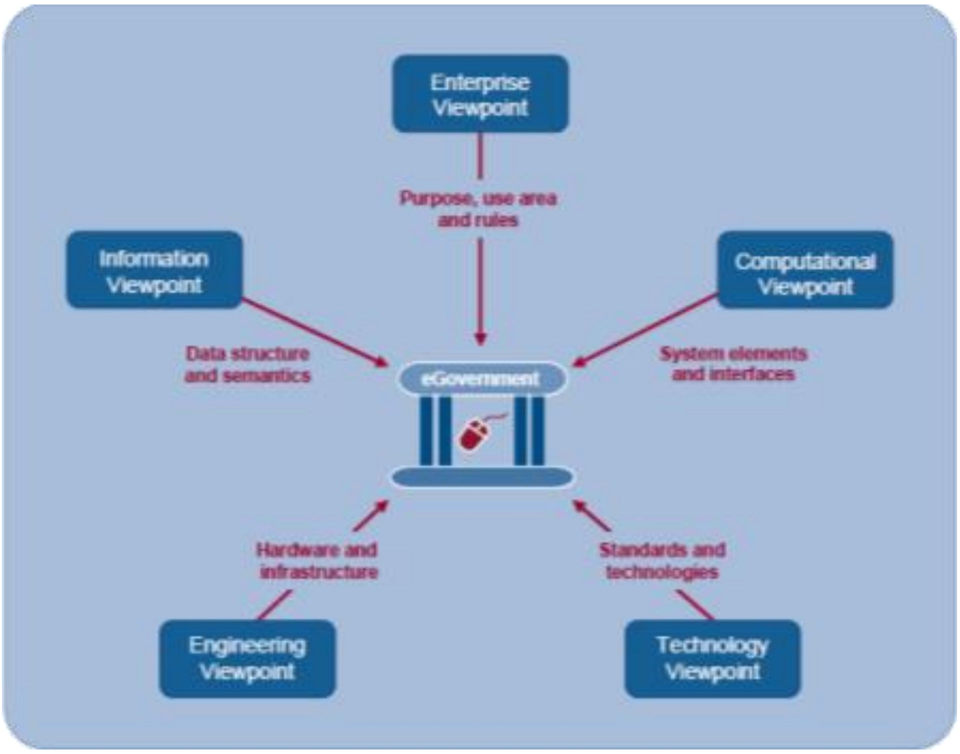
Part 1 focused on the Reference Model for SDIs and how standardisation efforts fit in this model; Part 2 aimed at describing Best Practices (BP) in SDI standardisation efforts and the method to describe such BP's; Part 3 describes the standards for data and metadata; Part 4 is dedicated to the service and technological standards and Part 5 focused on testing and validation aspects. Originally Part 6 would be added on the topic of architectures and standards for SDIs and e-Government. However, CEN/TC 287 became dormant, work on new items stopped and the management and eventual updates of technical reports and standards fall now under the responsibility of ISO/TC 211.

In 2013, the work on the Architectures and Standards for SDI and e-Government was picked up as part of the work under the ISA Action, European Union Location Framework (EULF). A first version of the document was developed and finalised in the course of 2014-2016. The current version of document starts from that version of the document.

1.3 Structure of this document

The report consists of seven sections of which 5 correspond to the different viewpoints of the Reference Model for Open and Distributed Processing (RM-ODP) (see **Figure 1**).

Figure 1: The RM-ODP model applied in the SDI and e-Government world (SAGA 4.0)



The current section, Section 1, or introduction. Section 2 introduces briefly the relevant standardisation activities in the SDI and e-Government worlds. Section 3 describes the starting point of each e-Government solution, i.e. the **business processes** they are supposed to support (enterprise viewpoint). Section 4 discusses the relationship between SDI and e-Government **architectures** (engineering viewpoint), while section 5 elaborates the **semantic aspects** in SDI and e-Government (information viewpoint). In section 6 the **Services** to access information, process it and to deliver results are explained (computational viewpoint). In Section 7 we provide an overview of **standards and technologies** on which e-Government solutions can rely (technological viewpoint).

It should be noted that the RM-ODP[4] model is not only used in the geospatial world. It is the basis for the ISO 19100 series of standards, which are, in turn, used as a basis for the INSPIRE specifications (Biancalana *et al*, 2010), as well as in the e-Government world, for example in the Standards and Architectures for eGovernment Applications (SAGA) document (SAGA, 2008).

[4] RM-ODP, is also known as ITU-T Rec. X.901-X.904 and ISO/IEC 10746. The standard is a joint effort by the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the Telecommunication Standardization Sector (ITU-T).

2 Relevant standardisation activities and technological developments

This section provides an overview of standardisation activities and bodies active in the geospatial and ICT fields and which are relevant for both the SDI and e-Government worlds. The section also summarises how recent technological developments are affecting the standardisation process.

2.1 Standardisation Activities

Several Standards Developing Organisations (SDO) develop semantic and technical standards to underpin SDI and e-Government activities. Usually they work together or build standards upon other standards developed by other SDOs. For SDI and e-Government activities, at least 7 SDOs play a crucial role:

- INSPIRE (through its Maintenance Implementation Group, MIG);
- ISO/TC 211[5] and the Open Geospatial Consortium (OGC) for the geospatial domain;
- the ISA/ISA[2] Programme, W3C and the Organisation for the Advancement of Structured Information Standards (OASIS) for the general ICT and e-Government domain; and
- the Object Management Group (OMG) for the modelling domain.

Table 1 provides an overview of different relevant standardisation efforts for SDI and e-Government activities, a summary of their domain, their relationship with other SDOs and how one can contribute to the standardisation process.

Table 1: Overview of relevant SDI and e-Government standardisation activities

Standardisation process	Description	Relationships	Participation / URL
INSPIRE Maintenance and Implementation Framework	The INSPIRE Maintenance and Implementation Group (MIG) and its sub-groups have a common work programme that is based on issues and change requests (e.g. related to data specifications) submitted by INSPIRE stakeholders. Examples of tasks are: exchange of experience and good practice; identify issues related to INSPIRE implementation and their priorities, etc.	ISO TC 211, OGC, ISA	Through INSPIRE Representatives in the Maintenance Implementation Group (MIG) http://inspire.ec.europa.eu/index.cfm/pageid/5160
ISO/TC 211 Geographic information / geomatics	ISO/TC 211 is responsible for the ISO geographic information series of standards. This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management, acquiring, processing, analysing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations.	CEN/TC 287, OGC	Through national ISO member organisation https://committee.iso.org/home/tc211

5 Also CEN/TC 287 plays an important role although this CEN committee does not develop its own standards but a procedure allows adopting European (CEN) standards from standards developed by the ISO/TC 211.

Standardisation process	Description	Relationships	Participation / URL
Open Geospatial Consortium	The Open Geospatial Consortium (OGC) is an international industry consortium of 521 companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. OGC® Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services and mainstream IT.	ISO/TC 211 (some OGC standards became ISO/TC 211 standards), W3C OGC-W3C Spatial Data on the Web Working Group[6]	The OGC is an open membership organisation. The OGC offers a range of membership options for industry, government, academic, research and not-for-profit organisations. Also individuals can become members of OGC. http://www.opengeospatial.org/
ISA (ISA^2)	ISA^2 is the follow-up programme to ISA, which ran from 2010-2015. ISA^2 started on 1 January 2016 and it will last until 31 December 2020. It was officially adopted on 25 November 2015 by the European Parliament and the Council of the European Union. ISA^2 supports a series of Actions to improve interoperability as a central means for modernising the public sector.	W3C, OASIS	Through member State representatives in different ISA^2 committees: ISA^2 Committee to steer the overall ISA^2 programme (with representatives from each Member State), the ISA^2 Coordination Group to assist the EC on ISA^2 Actions (with representatives from Member States and the EC), and, in the context of this work, the ISA^2 Working Group on Geospatial Solutions (previously the ISA Spatial Information Services Working Group) to advise and follow-up actions related to geospatial information solutions in the context of e-Government (with representatives from Member States). https://ec.europa.eu/isa2/home_en
OASIS	OASIS is a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society. OASIS promotes industry consensus and produces worldwide standards for security, Internet of Things, cloud computing, energy, content technologies, emergency management, and other areas.	W3C, ISA	OASIS members broadly represent the marketplace of public and private sector technology leaders, users, and influencers. The consortium has more than 5,000 participants representing over 600 organisations and individual members in 100 countries. Also individuals can become members. https://www.oasis-open.org/

6 The Spatial Data on the Web Use Cases and Requirements (UCR) Document is being released jointly as a W3C First Public Working Draft and as an OGC Public Discussion Paper: http://docs.opengeospatial.org/dp/15-074/15-074.html

Standardisation process	Description	Relationships	Participation / URL
OMG	The Object Management Group® (OMG®) is an international, open membership, not-for-profit technology standards consortium, founded in 1989. OMG's modelling standards, including the Unified Modelling Language (UML) and Model Driven Architecture (MDA), enable powerful visual design, execution and maintenance of software and other processes. OMG also hosts organisations such as the user-driven information-sharing Cloud Standards Customer Council (CSCC) and the IT industry software quality standardisation group, the Consortium for IT Software Quality (CISQ).	W3C, OASIS, ISA, OGC and ISO/TC 211	OMG standards are driven by vendors, end-users, academic institutions and government agencies. Its members include hundreds of organisations including software end-users in over two dozen vertical markets (from finance to healthcare and automotive to insurance) and virtually every large organisation in the technology industry.
W3C	The World Wide Web Consortium (W3C) is an international community where member organisations, full-time staff, and the public work together to develop Web standards. The W3C mission is to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure the long-term growth of the Web. W3C follows the Open Standards principles.	OASIS, ISA, OGC	W3C stimulates the public to participate in W3C via discussion lists, events, blogs, translations, and other means. Participation in Community and Business Groups is open to all Participation in W3C Working Groups (and other types) is open to W3C Members and other invited parties. Membership in W3C is open to all types of organisations (including commercial, educational and governmental entities) and individuals. http://www.w3.org/

2.2 SDI Standardisation and technological trends

Over the past 5 years, many new technological developments appeared or came to maturity. Most of them emanate from the ICT sector. Moreover, those trends were assessed and embraced by many other sectors, meaning that these new technologies were implemented in specific areas and contexts and adapted where appropriate. This happened also in the geospatial sector, and the shift from e-Government towards the Digital Transformation of Governments is largely influenced by those trends. Another observation that can be made is that the other way around, the e-Government world, Government in general and the ICT sector became more and more location-enabled. Geospatial data and technologies are less than before a 'niche' or 'special' domain meant for specialist. For example, W3C has shown an active interest in the geospatial sector, while also organisations before not active in the geospatial domain became active over the recent years.

In the following sub-sections some of the major technological trends are described and how they are relevant for the geospatial domain and for Digital Transformation of Governments, and how they influence standardisation. Also, the technology trends watch which was set-up by the OGC to monitor, assess and decide on their impact on existing geospatial standards and/or the need for new standards is briefly described.

2.2.1 Major technological trends

In table 2, an overview is provided that has been identified in many studies on technological trends and that have been mentioned in the ELISE Blueprint as being of relevance for the geospatial sector and the Digital Transformation of Government. The list is not exhaustive, and other topics could be added, especially when new trends would occur or existing trends would become relevant. The relevant (new) technologies are discussed in the respective sections, including definitions and details.

Table 2: Technological trends, their impact on standardisation activities and the section(s) in the report where they are discussed

Trends / topic	Standardization activity	Section(s)
Blockchain and Distributed Ledger Technology (DLT)	ISO/TC 307 has been set-up to develop a series of standards related to the technology (1 standard published, 10 under development). OGC has organised several dedicated sessions on Blockchain as part of its OGC Technical Committee activities and set-up a Blockchain and DLT Domain Working Group (DWG).	Section 3
Event Stream Processing (ESP)	ESP is closely linked to the IoT developments and Big Data analytics. OMG is developing and maintaining a comprehensive series of International Standards for Business Process Modelling. Several of those standards have been proposed for ESP and ESP Modelling. W3C has also developed some standards that are used in ESP (e.g. WS Eventing and WS Choreography).	Section 3
Application Programming Interfaces (API)	OpenAPI Initiative provides a specification for developing APIs across different sectors. OGC has set-up several new DWGs and Standards Working Groups (SWG) to develop APIs (e.g. Geocoding API DWG, Feature API DWG). A new series of standards, the OGC APIs are currently seeing light. Gartner describes three approaches or levels for standardisation: platform-specific APIs, Consortium specific APIs and APIs according to international standards	Section 4, 6

Trends / topic	Standardization activity	Section(s)
Digital platforms7, the cloud and the Fog & the Edge	Many Digital Platforms do not apply International Standards. Many efforts have been performed, or are ongoing, in the field of Earth Observation, e.g. the Copernicus services which are set-up as collaborative platforms and are supported by the DIAS for helping users to process data. OGC has set-up specific EO exploitation platform DWG Digital platforms developments are closely linked to IoT, Artificial Intelligence and Big Data and require/make use of the cloud and the Fog & Edge, where the OGC prepared a white paper on the role of geospatial in cloud-edge and fog computing	Section 4, 6
Internet of Things	IEEE has developed a series of standards related to the IoT, as well as a draft standard for an Architectural Framework for their IoT Working Group. ETSI also plays an important role on the IoT standardisation, being one of the founding members of oneM2M (Machine to Machine global standards initiative). The ISO/IEC Joint TC 1/SC 41 has also developed a reference architecture. OGC has makes the link to the IoT in several initiatives such in the SensorThings SWG	Section 4, 5, 6
Geospatial data on the web and the semantic web	Activities in the context of the implementation of SDIs (e.g. Geonovum projects) W3C created the dataset exchange working group (DXWG) in close collaboration with OGC members The OGC Spatial Data on the Web Working Group (SDWWG) has been set-up as a subgroup of the OGC Geosemantics DWG and collaborates with a W3C working group with the same name. ISO/TC 211 work on ontologies	Section 5, 6
Big data, big data analytics, machine learning and AI	ISO/IEC JTC 1/SC 42 have a joint initiative on Artificial intelligence and are working on a reference architecture for big data, as well as a vocabulary ISO/IEC are developing a series of standards for the domain. OGC has set-up a Big Data DWG and an Artificial Intelligence in Geoinformatics DWG. Standards for Machine learning are discussed in many different sectors (health, biology, earth observation …)	Section 4, 5
New data models	Activities in the context of INSPIRE, environmental monitoring by the (EEA) and ELISE Standardisation in other fields (e.g. architecture/engineering with BIM) picked-up by other SDOs (e.g. the geospatial field)	Section 5

[7] Digital Platforms for collaborative government are sometimes confused with regular data or information platforms.

Trends / topic	Standardization activity	Section(s)
	OGC is very active to apply basic data models in other environments: e.g. IndoorGML, CityGML, WaterGML …	
Data archiving	ISA² has a specific action related to data archiving: Facilitating archive management across Europe. ISO standards exist with regard to digital archiving: ISO/TC 46/SC 11 - Archives/records management. OGC has also set-up a Data Preservation DWG.	Section 5
New generation of geospatial web services and microservices	OGC is moving from 'traditional' web interfaces (web services) to services and APIs, e.g. WFS 3.0. Several OGC APIs are in the making. Microservices are part of the traditional web services but consisting of smaller components and allow apps to be built that consist of connected services. Mainly of them are driven by individual companies.	Section 6
Sensor Web Enablement (SWE) and SensorThings	ISO, IEEE and IEC have developed basic standards for sensors, both hard- and soft-sided. OGC conducts long-standing activities with a series of standards for SWE and a dedicated DWG and SWG. New OGC SensorThings API standard and SWG	Section 6

The technological trends mentioned in table 2 are certainly not the only ones that exist, but they have been identified in the EULF Blueprint as potentially important for the Digital Transformation of Governments. Therefore, they are discussed in more detail in the next sections, as part of the different viewpoints. It should also be noted that most of them are interconnected: e.g. the IoT is not possible without cloud-fog-edge computing, while the SWE is closely linked to IoT developments.

2.2.2 Technology trends watch from OGC

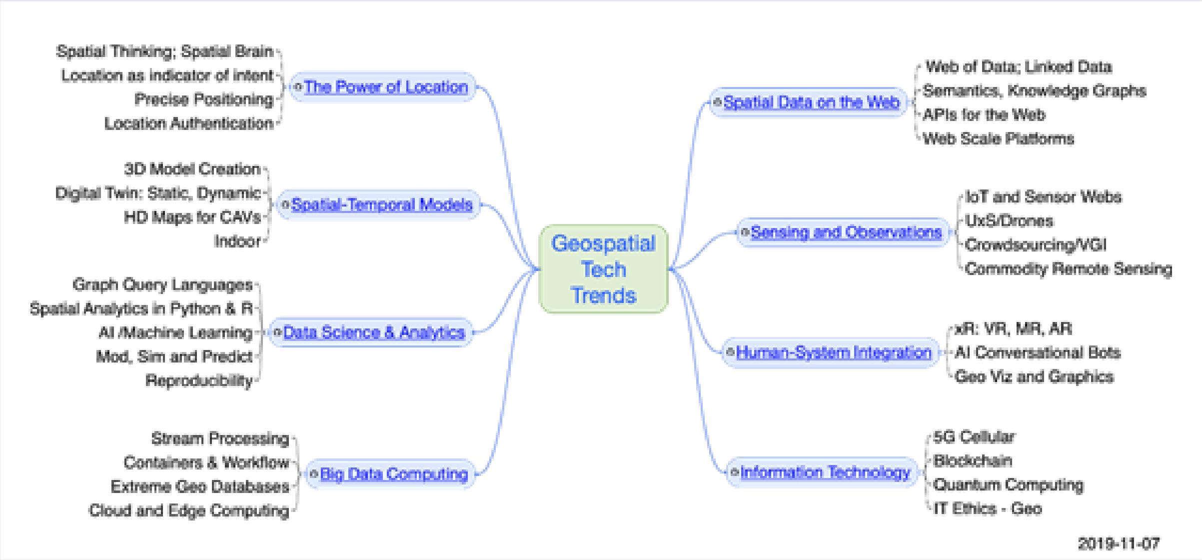
It is clear that, as SDIs continue to develop worldwide and especially in Europe related to INSPIRE, they should not be considered as static or fixed constructs. They are evolving because of societal and technological developments. Societal examples include increased participation of citizens in policy and decision-making. Technology-wise there are many, often inter-connected, emerging technologies. It is unavoidable that such issues impact on the architectures and standards an SDI is built upon, as well as their use for digital public services.

The OGC has developed an approach to monitor and assess technology trends that might / will have an impact on the geospatial industry, the so-called Technology Trends Watch (TTW). The TTW is part of the OGC innovation strategy that includes maintaining the OGC Standards Baseline while simultaneously addressing trends in technology and markets (OGC, 2020). The OGC TTW surveys and characterises trends across ICT, as well as the science and technologies that support the collection, processing, and understanding of geospatial information. The TTW approach is developed based on a survey of technology forecasting methods, e.g., Persistent Forecasting of Disruptive Technologies, US National Academies (NRC, 2010). The products of the TTW are updated and posted by the OGC on a public Github page[8] every quarter. What is important and interesting in the approach is the effort to assess how general trends affect the geospatial domain, and what it means for standardisation efforts.

[8] https://github.com/opengeospatial/OGC-Technology-Trends/

Figure 2 provides a mindmap of the current insights in the relevant technological trends for the OGC community (OGC, 2017).

Figure 2: Mindmap of the technological trends impacting the geospatial sector as identified by the OGC (2019)



Every quarter, the mindmap is updated and for particular areas more detailed roadmaps are developed including the current status, the target and the way to go, with focus on what could / must be done with regard to the standards. OGC is experimenting to automate the 'discovery' of new trends that might be/become relevant for the geospatial field by using web scraping technologies.

For ELISE, this approach is relevant and it is recommended that in future developments of, for example, INSPIRE, the TTW is used a source of information to make decisions on new activities, including helping ELISE to prepare new studies.

3 Governmental business processes – Enterprise viewpoint

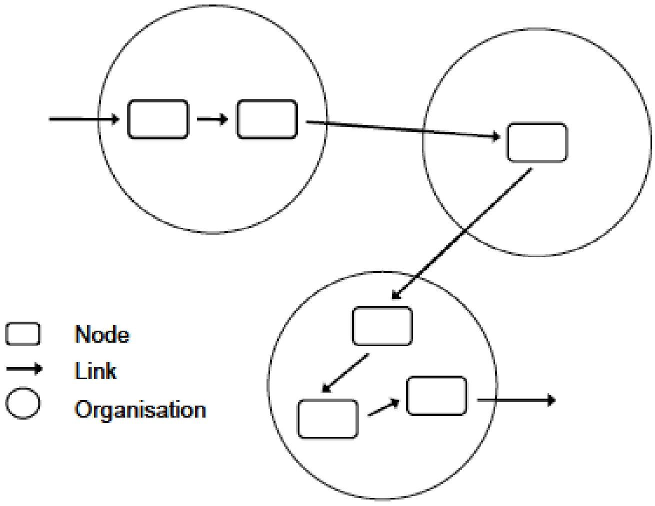
This section describes the business processes that form the basis of government activities and of e-Government in particular. We explain what they are and how they work, the importance of the different types of interactions within the business processes, the role of front and back offices and of (geo-) brokers. Finally we describe the role location information plays (or can play) in the context of e-Government business processes, and the standards and tools for process modelling and management. A full understanding of processes and their integration of geospatial resources into e-government services can be seen as a 'fundamental change' for some organisations from the digital transformation perspective. This section represents the **enterprise viewpoint** of '*Architectures and Standards for SDI and e-Government*'.

3.1 Business processes

A business process is defined as the way in which organisations create products, services or policies (Dessers *et al.*, 2010). It is a succession of structured and interconnected activities across time and space which, starting from one or more identifiable inputs, results in one or a set of clearly defined outputs in the form of products or services. The output in the context of e-Government can vary: it can be, for example, a decision, a figure, a map, a document or a data set, amongst others. By analysing processes, it is also possible to adopt the users' points of view (Davenport, 1993). Therefore, it is the most pertinent unit of analysis for e-Governmental practices (which focus on the interaction between government, businesses and citizens). Rummler and Brache (1995) make the distinction between primary processes, the operational processes that create the output, and secondary or supporting processes. NORA 3.0, the Dutch e-Government initiative, also considers steering processes (2012). Although a process can take place entirely within a single organisation, processes in which more than one organisation is involved are gaining importance (Gereffi *et al.*, 2005; Huws & Ramioul, 2006). This is illustrated in

Figure **2**.

Figure 3: The process as a chain between and within organisations (Dessers *et al.*, 2010)



Often a process is divided into several sub-processes due to complexity that can, in turn, be sub-divided into a series of activities and tasks[9]. Therefore, the simple input–throughput–output model (Porter, 1985) consists of several interconnected input–throughput–output chains whereby the output of one sub-process serves as the input for another sub-process. For business processes dealing with policy preparation, monitoring and evaluation, decision-making or service provision, the notion of data and information flows is crucial (Roche & Caron, 2004). Indeed, to perform the different tasks in such processes, data and information are needed as input, in order to process them and to create new data and information that can serve other organisations, policy-makers or even individual citizens. Table 2 provides some examples of business processes which might benefit from improved interoperability of location data and services (JRC, 2014; Vandenbroucke *et al.*, 2014 and SAGA 4.0, 2008).

Table 2: Examples of e-Government Business Processes

Examples of e-Government Business processes	
Registration of citizens	Maintenance of addresses
Registration of companies	Registration of real property
Taxation of citizens	Design of spatial zoning plans
Management of patient's health records	Monitoring animal transport
Planning of public transport	Procurement for construction and civil engineering projects
Issuing building permits	Management of government properties
Issuing environment-related permits	Assessing the socio-environmental impact of a planned TEN-T project
Delineating flood areas to provide "space for water"	

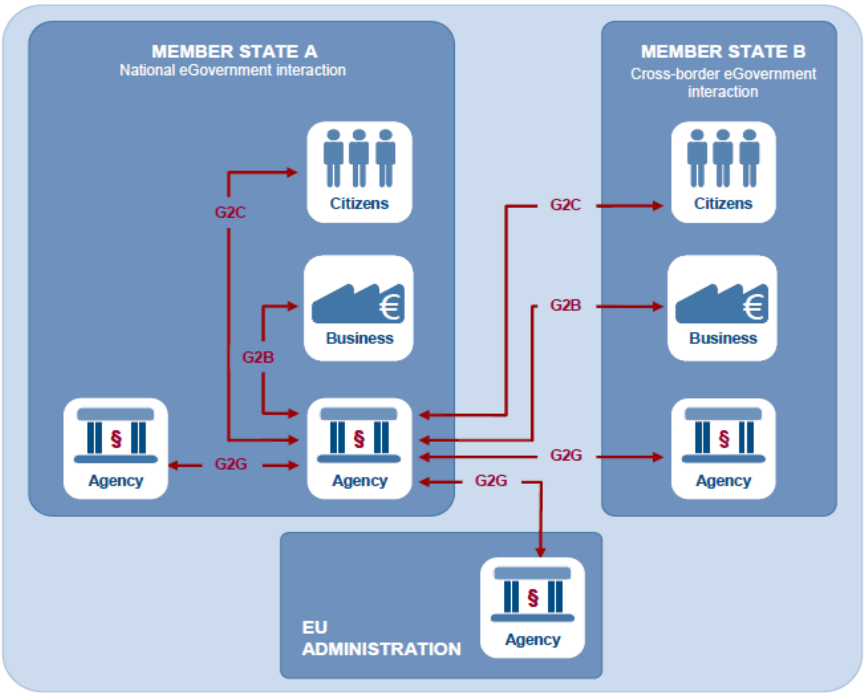
e-Government business processes contain many (different types of) interactions involving public authorities, business and/or citizens. Part of the processes are run in the background (back office) while there is also – due the necessary interactions with the different actors – a front office. Finally, often there is also a mediator or broker to help in steering the process. These different aspects are discussed in more detail in the next sub-sections.

[9] NORA 3.0, the Reference Architecture for the Dutch Government defines a hierarchy of processes: process-chains consisting of a number of business processes which in their turn consist of one or more work processes, further subdivided in process-steps and actions (2007).

3.1.1 G2G, G2B and G2C Interactions

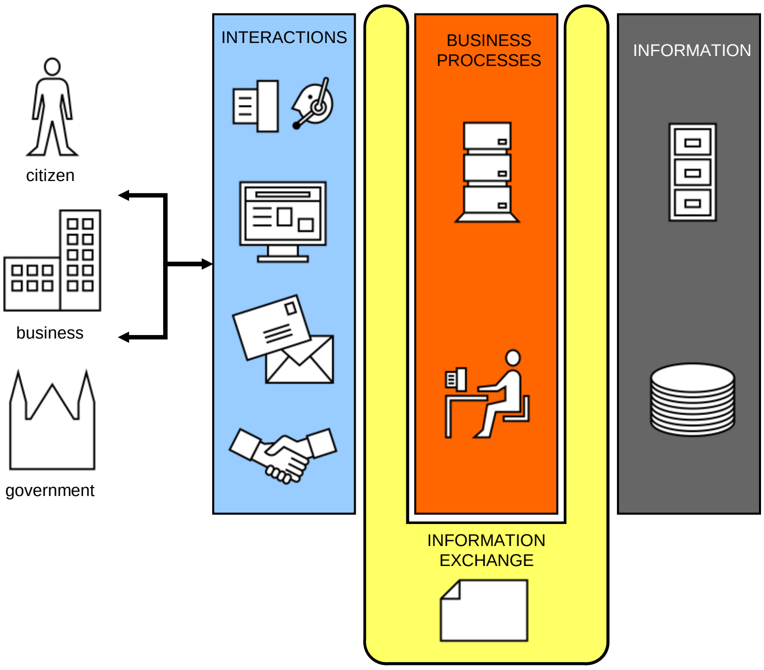
Within the context of e-Government business processes many interactions take place: between Government and Citizens (G2C), between Government and Businesses (G2B) and/or between Government and Government (G2G). **Figure 4** provides an example of national, cross-border and EU interactions.

Figure 4: National and cross-border e-Government interactions between Governments, Citizens and businesses (SAGA 4.0)



Interactions can be of different types: physical at a desk (e.g. in the municipality), via phone calls and call centres, through regular mail or e-mail, or via websites or web applications. Machine-to-Machine interactions can be part of the processes but are seen as a separate category.

Figure 5: Business processes involve interactions between different actors (based on NORA 2.0 and 3.0)



Within each e-Government process such interactions can occur multiple times: a citizen can contact or be contacted by an authority several times, e.g. in order to request additional information in the context of a building permit process. Moreover, some processes might entail several iterations before a decision is taken and the process comes to an end. Over the past few years, digital interactions, mainly through the Internet, have become more prominent. In The Netherlands, for example, citizens can access their Personal Internet Pages (PIPs) through a portal. The use of personal e-ID cards for secure access[10] is also an important aspect of technical solutions and an e-Government architecture.

3.1.2 Back and front offices, and brokers

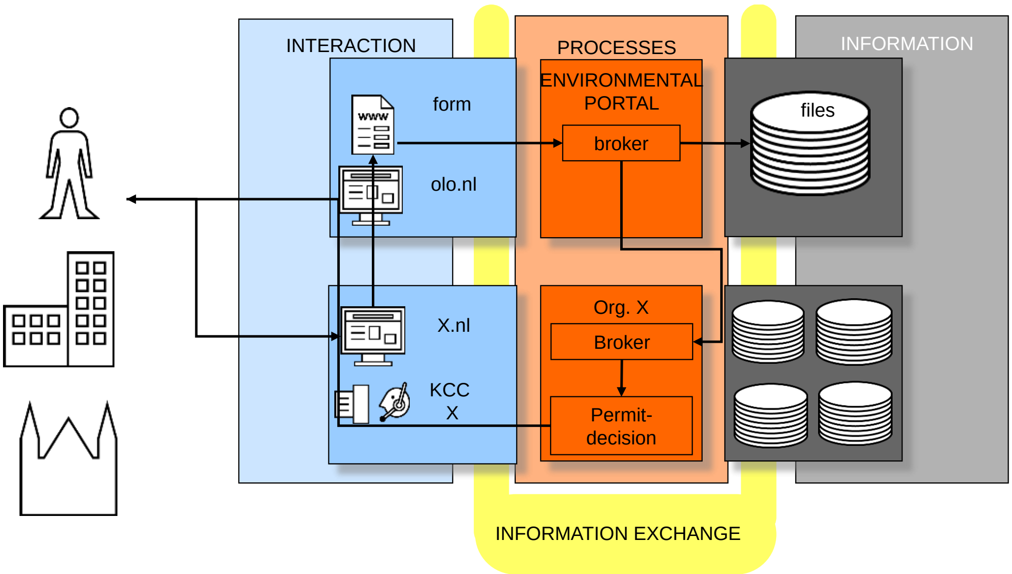
Developers of e-Government solutions draw a distinction between front and back offices. The front office is the place where the citizen and business interaction takes place with government, either physically or via computers (or other devices). For citizens and businesses, and public administrations themselves, e-Government solutions usually provide several portals or other web applications through which the interactions of the different business processes take place. At the same time we see efforts towards offering a one-stop-shop, usually also in the form of a central portal, where all the interactions for different business processes take place.

The back-office is the place where no user interaction takes place. Part of the business process takes place in the back-office, often in a batch oriented way. The machine-to-machine interactions are also part of the back-office. Back-office activities often take place in closed (and secured) networks. In this context, also the role of brokers[11] should be understood. In a process, a broker helps to determine how the process interacts with other processes and services within the overall system. The broker mediates the interaction among different (components of) systems without human intervention. **Figure 6** gives an example of process in which brokers play a steering role.

Figure 6: Example process with a broker playing a steering role (based on NORA 2.0 and 3.0)

[10] Other mechanisms for secure access by citizens exist, but e-ID cards and e-ID card readers are becoming more and more common in EU Member States. There are specific actions on this topic in the ISA/ISA² programme, e.g. in the STORK initiative and related actions and the eIDAS Regulation (EU) 910/2014

[11] If the broker is treating geospatial data it is called a geo-broker. The concept of mediation is the same.



In this example, a citizen (or business) needs to obtain an environmental permit. They access a website of the local municipality. The website then links through to the environmental portal. The citizen then fills in a web form to request a permit. The resulting environmental permit request is written to a request database. The request is then redirected by the broker to the coordinating system of the department responsible for processing the request for the environmental permit. The broker of that department then responds with the answer regarding the request to the citizen – for example by mail, SMS or via the portal. While the request is in process, the citizen may check the status of the request. In some cases, the decision step might require a physical meeting with other members of the department and possibly other experts.

This example illustrates how a process is a combination of interactions between governments, and between governments and their citizens, and how the process can be steered by adding brokers.

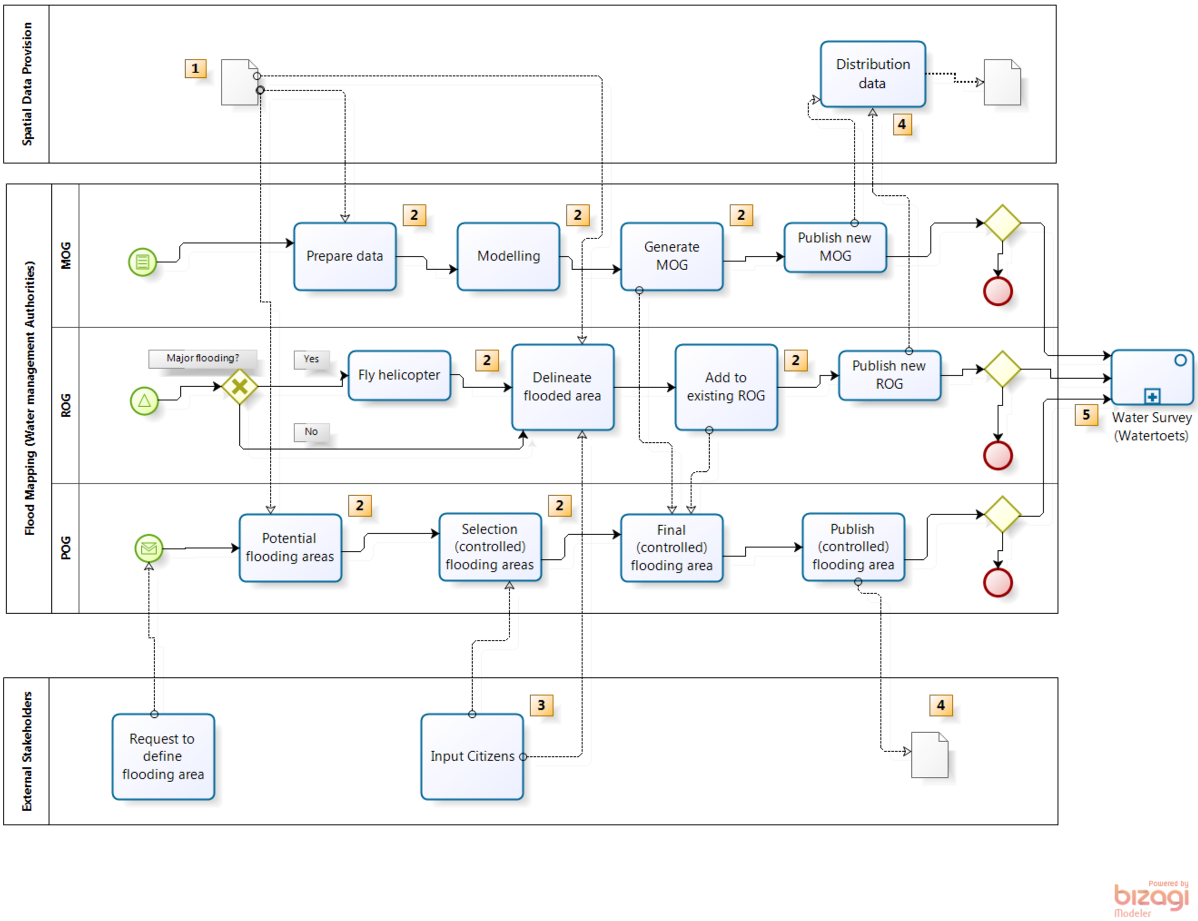
3.2 The role of location information in business processes

In the context e-Government business processes, a lot of data and information are consumed (input), transmitted (it flows) and processed (throughput) in order to create new information (output). In most of these processes there is often a mixture of different types of data, including location information. Authentic or base registers will often play a crucial role: e.g. addresses, cadastral parcels, buildings, but also persons and businesses. In addition, e-Government business processes not only 'consume' location information (whether the location information is visualised or not), but may also create location information. For example, the generation of a transportation route and the calculation of the travel time in the process "monitoring of animal transport" or the delineation of a potential buffer zone for flooding in the process "mapping of flooding areas".

A business process model of the flood mapping process is provided in

Figure 7. It shows a complete schema developed using the Business Process Modelling Notation (BPMN) language (see Section 3.3) of the definition of recently flooded areas (ROG), the flooding areas generated by models (MOG) and the flood buffer zones (POG). It indicates with orange numbers in boxes where in the process location information is accessed, processed and/or distributed.

Figure 7: The flood mapping process mapped using BPMN (Vandenbroucke et al, 2013)



This example of an e-Government business process is a representative case in which integration of location data and services is critical. However, many other e-Government business processes may only use location information as secondary or background information, or even not (yet) at all[12]. One of the objectives of the EULF Blueprint's Digital Government Integration focus area is to understand existing e-Government processes, to map them using business process modelling standards (see Section 3.3) and to get a better insight into where within these existing processes location information and location enabled e-Government services might improve the (performance of the) process.

3.3 Standards and tools for managing business processes

There are several international standards for business process modelling. In this section we present the most widely used ones as an example.

Business Process Management Notation[13] – BPMN

Business Process Model and Notation (BPMN), an Open Management Group (OMG) standard, is a graphical approach for defining business processes in a business process model. BPMN provides organisations and process owners with the capability of understanding their internal and external business procedures in a graphical notation and gives them the ability to communicate these procedures in a standard manner. The graphical notation facilitates the understanding of how actors in the process interact and how data flows. It also provides insight in the performance of the interactions and transactions between the organisations. This helps organisations to understand better how they work and where the other actors in the process contribute, possibly enabling them to adjust the way interactions take place. The Business Process Management Initiative

12 The Flemish Government started a few years ago a systematic description of all its business processes to improve their management and to streamline them.

13 See http://www.bpmn.org/

(BPMI) developed BPMN, which has been maintained by the Object Management Group since the two organisations merged in 2005. Since March 2011, BPMN is 2.0 is the most current version.

Business Process Execution Language - BPEL

BPEL (Business Process Execution Language) is an XML-based language that allows Web services in a Service Oriented Architecture[14] (SOA) to interconnect and share data. Programmers use BPEL to define how a business process that involves web services will be executed. BPEL messages are typically used to invoke remote services, orchestrate process execution and manage events and exceptions. BPEL is often associated with Business Process Model and Notation (BPMN). In fact, a BPMN schema can be transformed 'automatically' in BPEL to make it executable. In many organisations, analysts use BPMN to visualise business processes and developers transform the visualisations to BPEL for execution. BPEL was developed by OASIS (full name is WS-BPEL). BPEL's focus on modern business processes, plus the histories of WSFL (Web Services Flow Language) and XLANG, led BPEL to adopt web services as its external communication mechanism. Thus, BPEL's messaging facilities depend on the use of the Web Services Description Language (WSDL) to describe outgoing and incoming messages.

Archimate

ArchiMate®, an Open Group Standard, is an open and independent modelling language for enterprise architecture that is supported by different tool vendors. ArchiMate provides instruments to enable enterprise architects to describe, analyse and visualise the relationships among business domains in an unambiguous way. ArchiMate offers a common language for describing the construction and operation of business processes, organisational structures, information flows, IT systems, and technical infrastructure. This insight helps stakeholders to design, assess, and communicate the consequences of decisions and changes within and between these business domains.

Examples of tools for Business Process modelling

Enterprise Architect (proprietary)

"Enterprise Architect is a comprehensive UML analysis and design tool for UML, SysML, BPMN and many other technologies. It covers software development from requirements gathering through to the analysis stages, design models, testing and maintenance. Enterprise Architect supports analysts, testers, project managers, quality control staff and deployment teams.

Bizagi (Freeware)

Bizagi is used to define, design and document business processes by using data layer reuse rules, forms and data, keeping unnecessary complexities out of the BPMN process modelling and comprising a rich toolkit of components and services that enables dynamic interaction with any external system. Bizagi consists of three parts: Modeller to design and map the process; Studio turns the process models into running applications to distribute them across the organisation; Engine executes processes and delivers them to the desktops and mobiles of the business user.

Modelio (Open Source)

Is an open source modelling environment that supports modelling of UML, BPMN, Archimate, TOGAF, amongst others. Modelio combines BPMN and UML in one tool, with dedicated diagrams to support business process modelling. Modelio is licensed under the GPL v3 license. There is an API for developers and an extensive community with different levels of contributor: from those without expertise to advanced contributors. The community shares results of their experiments with innovation modelling technologies in various areas including: Embedded Systems, Cyber-Physical Systems, Cloud and Big Data.

ADONIS (Freeware)

Is a cloud-based community tool, that supports BPMN modelling with the aim to share the results across departments in an organisation or across organisations. The tool allows modelling, testing & validation and analysing processes. It also includes business scenario support and supports the integration of documents. There is a RESTful API for portal integration and web-based interfaces.

[14] A Service Oriented Architecture is an architectural pattern in computer software design in which application components provide services to other components via a communications protocol, typically over a network. The principles of service-orientation are independent of any vendor, product or technology based

3.4 New developments

In the context of business processes in governments, specific new technological developments are of importance, although they are in an early stage of implementation in the geospatial sector: Examples include blockchain and distributed ledger technologies, and event stream processing and complex event processing. Both developments are briefly discussed here, some examples on their application in the geospatial field are given and relevant standards and standardisation efforts are identified.

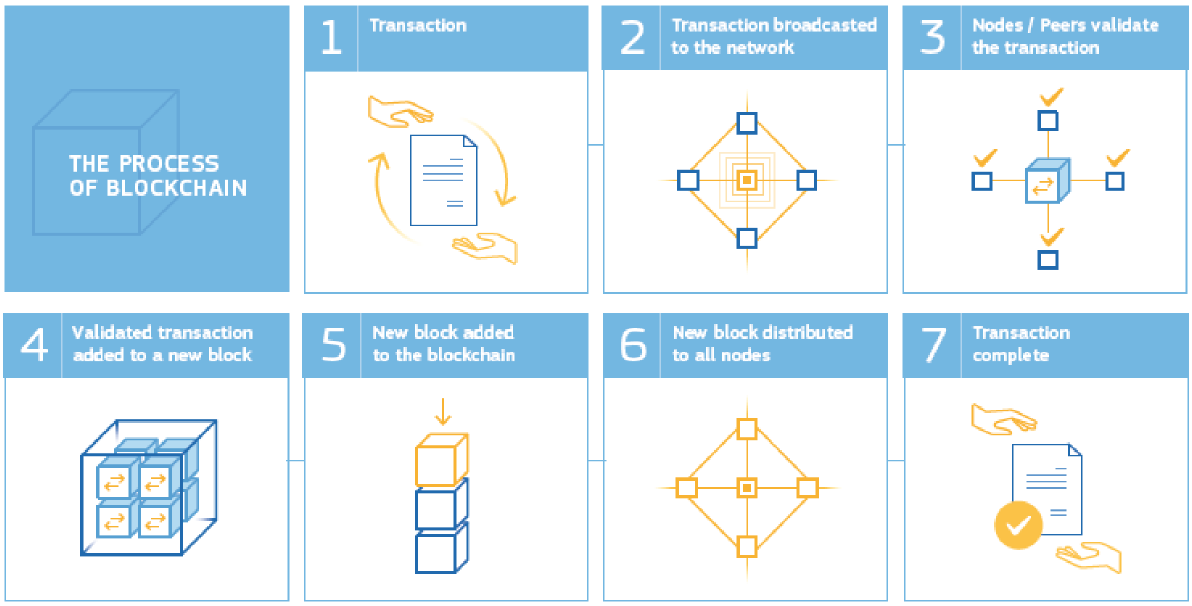
3.4.1 Blockchain and Distributed Ledger Technology

Distributed Ledger Technology (DLT) refers to the protocols and supporting infrastructure that allow computers in different locations to propose and validate transactions and update records in a synchronised way across a network (Allessie *et al.*, 2019). Each node in the network has exactly the same data records. There is no single database controlled by a central party. Blockchain is a type of distributed ledger technology in which transactions are sequentially grouped into blocks. Each block is chained to the previous block and immutably recorded across a peer-to-peer network, using cryptographic trust and assurance mechanisms. Depending on the implementation, transactions can include programmable behaviour (Allessie et al, 2019). Each new block in the chain is encrypted and contains a hash based on the exact content and also the hash of the previous block. This creates an immutable chain linking all blocks up until the first block. New transactions are verified by the other nodes in the network before they are added to the chain.

Blockchains are categorised as public if anyone can access and read their content, or private when only authorised entities have access. In a different categorisation, if anyone can execute/validate transactions the blockchain is permission-less, if one needs to be authorised to execute or validate transactions, the blockchain is permissioned. This gives 4 different blockchain types which are used for different purposes.

Another important feature implemented in some blockchains are smart contracts. These are programs that are executed automatically based on a transaction or on the state of the system.

Figure 8: The process of Blockchain (Nascimento *et al.*, 2019)



DLT and blockchain can have a number of advantages over traditional centralised systems (World Bank, 2017):

- Decentralisation and disintermediation. The need for an intermediary or central authority who controls the ledger is removed (although in a permissioned system part of this role still exists). This can result in lower costs, better scalability and faster time to market.
- Transparency and auditability because all network members have a full copy of the ledger and changes are made by consensus only.
- Automation and programmability. Smart contracts can be executed as soon as a transaction is completed. And results of the smart contract is immediate.

- Immutability and verifiability. DLT can provide an immutable and verifiable audit trail of transactions of any digital or physical asset. As entities cannot be changed, data integrity is safeguarded.

- Enhanced security due to the physical decentralisation of the storage. This eliminates the single point of failure in a centralised system.

Applying blockchain technology in digital governments can result in these main benefits (Allessie *et al.*, 2019):

- Reduced economic costs, time and complexity in inter-governmental and public-private information exchanges that enhance the administrative function of governments.

- Reduction of bureaucracy, discretionary power and corruption, induced by the use of distributed ledgers and programmable smart contracts.

- Increased automation, transparency, auditability and accountability of information in governmental registries for the benefit of citizens.

- Increased trust of citizens and companies in governmental processes and recordkeeping driven by the use of algorithms which are no longer under the sole control of government.

It should be noted that digital public services often process personal data that may need to be kept outside of blockchains, as GDPR establishes rights for individuals to ask for their data to be deleted.

In 2016, ISO established technical committee ISO/TC 307 to develop new standards on blockchain and a roadmap report was published in 2017. ISO/TC 211 the technical committee for geospatial information and geomatics established a liaison with ISO/TC 307. To date, the committee has published one standard[15], while 10 are under development. OGC explored the geospatial standardisation in DLT, concluding that the initial focus should be in how location is represented in blockchains (Hobona G *et al.*, 2018). In 2019, OGC established a Blockchain and Distributed Ledger Technologies DWG (BDLT DWG) to build understanding of the potential requirements for geospatial standardisation within Blockchain and DLT. Another important initiative is FOAM, committed to providing spatial protocols, standards, and applications that offer a higher level of security and resiliency than conventional geospatial technologies and location-based services (FOAM Whitepaper, 2018[16]). The OGC discussion paper concluded that the FOAM protocols and the related Crypto-Spatial Coordinates should be considered to become an OGC standard (Hobona G et al, 2018).

It is clear that Blockchains and DLT are closely linked to the business processes orientation. The technology is applied a lot by businesses and especially the banking sector, but it is also emerging in the geospatial sector. In the OGC TC meeting held in Charlotte in 2018, ESRI gave examples of the application of the technology (using ArcGIS and Apla Blockchain), presenting a Land Registry Geo-Blockchain Application to monitor and control land transactions. Similar efforts and experiments are ongoing in The Netherlands and Sweden. At the same event, another example of the application of blockchain technology was given, i.e. to have a mechanism called Proof of Location based on the need to prove to 3rd parties where you are, where you have been, and when. Examples of applications given were: autonomous vehicles; gaming/AR (Pokemon Go); mapping & crowdsourced point of interest data and cryptocurrency (token drops). Location would be derived from multiple signals, such as "sensor fusion": accelerometer, GNSS, WiFi, cell towers and Bluetooth.

Currently (early 2020) the OGC Blockchain and DLT DWG is focusing on the following activities: 1) to identify and define use cases; 2) to discuss case studies for Blockchain and OGC Service Architecture interoperability; 3) to discuss encryption and security implications of Blockchain and other DLT; 4) to explore issues of Trust and Proof-of-Location; 5) to explore Smart Contracts technology; 6) to define any areas for standardisation and create necessary Standards Working Groups to address the gaps in the OGC standards baseline and 7) to explore the potential for an interoperability pilots and testbeds that help define geospatial architectures that benefit from Blockchain and other DLT (OGC, 2020).

[15] ISO/TR 23455:2019 - Blockchain and distributed ledger technologies — Overview of and interactions between smart contracts in blockchain and distributed ledger technology systems

[16] https://foam.space/publicAssets/FOAM_Whitepaper.pdf

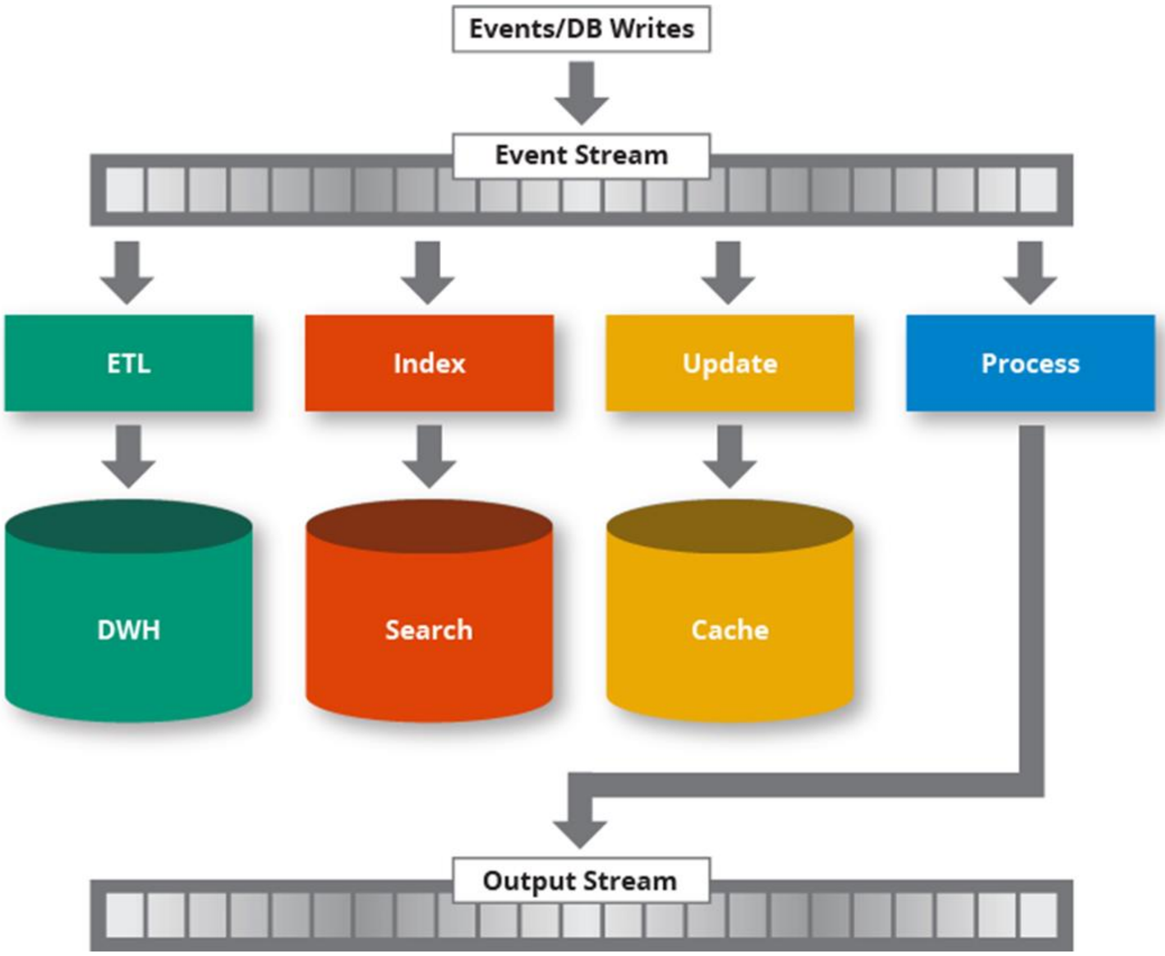
3.4.2 Event Stream Processing and Complex Event Processing

Event Stream Processing (ESP) and Complex Event Processing (CEP) are two terms often referring to the same concept. They are technologies emerging in the context of our ever-growing amount of data gathered through sensors, things, etc. So it is very much interrelated with IoT and Big Data developments although the concept of CEP exists already since the 1990s (especially in business, e.g. sales, traffic and weather data, etc.).

More specifically, ESP is the process of analysing time-based data in ‘real-time’, as the data are being collected/created and before they are stored, even at the moment that the data are streaming from one device to another (Bolan, 2019). It is very different from the traditional data treatment patterns in governments in which agents collect and store the data (nowadays that might be in the cloud), then process and analyse the data, and finally (eventually) publish and share the results. In ESP, the analysis is done as the stream of data is coming, while the results are immediately published/shared.

ESP is often viewed as complementary to batch processing. Batch processing is about handling a large set of static data, named “data at rest”, while event stream processing is about treating a constant flow of data, also named “data in motion” (Hazelcast, 2019). Processing can take many forms: aggregation (e.g. sum, mean, and standard deviation), analytics (e.g. predicting a future event based on patterns in the data), transformations (e.g. changing a number into a date format), enrichment (e.g., combining the data with other data sources to create more context and meaning) and ingestion (e.g., inserting the data into a database). The technological environment for implementing ESP is two-fold: 1) a system to capture and store the event data and 2) an environment to process the data streams (e.g. Hazelcast Jet), see Figure 9.

Figure 9: ESP - Even Stream Processing (Hazelcast, 2019)



ESP can occur in different places (McNeill, 2019[17]). 1) 'At-the-edge': the data are processed on the same device from which it is streaming (see also Fog & Edge computing). 2) 'In-stream': processing occurs as data streams from one device to another, or from multiple sensors to an aggregation point. 3) 'At-rest': processing is happening when there is a historical repository of data, which can include both data saved from the event stream, as well as other stored information.

According to Paschke *et al*. (2011), there is a need for multiple standards for ESP and CEP. They argue that in rule-based Event Processing and Complex Event Processing (CEP), many areas of software development re-use existing technologies and methodologies, allowing their related standards to be re-used as well. Other standards may need to be developed to replace or augment existing standards. They propose a CEP Standards Reference Model including the use of standards for Business Process Modelling from OMG such as: BMM (Business Motivation Model), SBVR (Semantics of Business Vocabulary and Rules), BPMN (Business Process Model and Notation), the Event and Agent Meta Models. Standards from other organisations are also considered, such as BPEL (Business Process Execution Language from OASIS), as well as WS Eventing and WS Choreography from W3C. However, it seems that there is not one overall approach yet for applying a coherent set of standards and a lot of the activities are still in the research / experimental phase, and different solutions might be applied by different vendors.

Examples of ESP in the geospatial world are mostly related to Location Based Services (LBS) and Intelligent Transport Systems (ITS) in the sectors of transport. Also, weather services might make use of the technology. An example is the continuous streaming of data from weather stations to weather monitoring centres generating not only maps of the current weather, but also feeding data to weather forecasting models (ECFMW) to predict short- and medium-term weather conditions (see www.windy.com). While traditional SDIs usually contain many relatively 'static' geospatial datasets (e.g. soils), or datasets representing a phenomena at a certain point in time (e.g. CORINE Land Cover of Year X), events and event streams are dynamic by nature. Of course, events and event streams can be stored as part of the SDI data store, but EPS also allows event streams to be used together with SDI reference datasets without such storage (e.g. for air quality measurements linked to monitoring stations).

3.5 Conclusions

Analysing e-Government activities from the business process perspective allows us not only to understand, manage and improve the information flows and the many interactions that take place between public administrations, and between the administrations and citizens/businesses, but also to identify the places where location information and location based services can add value to the process. While the development of SDIs is usually focussing on the infrastructure *per se*, the business process perspective enables a shift of focus more to the uptake of the components of the infrastructure by the users in the processes. Many standards and tools exist to map and manage the process and to automate the execution of services that support these processes. Current technological developments that influence the way governmental and related process might run, are blockchain and DLT technologies, as well as Event Stream Processing. The first technology will help building trust in processes in which transactions are important, while EST can help to build innovative applications in the transport or environment sectors.

[17] https://www.sas.com/en_us/insights/articles/big-data/3-things-about-event-stream-processing.html

4 SDI and e-Government architectures – Engineering viewpoint

This section describes the European Interoperability Strategy (EIS) and Framework (EIF) that form the basis for the European Interoperability Reference Architecture (EIRA) for Digital Government. It discusses the different components of such an architecture and how an SDI architecture fits in this picture. Some of the major frameworks and standards for describing architectures are also discussed. New developments with regard architectures such as API's, Meshed Applications and Service Architectures, Microservices, as well as Digital Platforms and Cloud-Fog-Edge Computing are introduced as well. This section represents the **engineering viewpoint** of '*Architectures and Standards for SDI and Digital Government*'. In order to better understand the Digital Government and Geospatial worlds, their respective architectures, implicit or explicit, are described, and their differences and similarities analysed. Standards for architecture design and new developments are discussed as well.

4.1 e-Government and the EIS, EIF, EIA and EIRA

The European Interoperability Strategy (EIS) was developed by EC DG DIGIT. The EIS aims to provide guidance and to define the priority actions needed to improve interaction, exchange and cooperation among European public administrations across borders and across sectors for the delivery of European public services as part of e-Government strategies. The strategy was prepared during the IDABC Programme and finalised after a public consultation under the ISA Programme (European Commission, 2010). The vision on the EIS acknowledges *"the importance of trusted information exchange enabled by commonly agreed, cohesive and coordinated interoperability initiatives, including completion of the legal environment, development of interoperability frameworks, and agreements on interoperability standards and rules"* (European Commission, 2010). Therefore, one of the three major clusters of activities is the development of an Interoperability Architecture. The cluster defined the following priority actions:

- To develop a joint vision on an interoperability architecture;
- To provide guidance on architecture domains where Member States share a common interest;
- To ensure the systematic reuse of architectural building blocks by the Commission when developing services to be used by the Member States.

The European Interoperability Framework v.2 (EIF) builds further on the EIS targeting three objectives:

- To promote and support the delivery of European public services by fostering cross-border and cross-sectoral interoperability;
- To guide public administrations in their work to provide European public services to businesses and citizens;
- To complement and tie together the various National Interoperability Frameworks (NIFs) at European level.

The EIF is built around the concept of European Public Services for e-Government. These are "cross-border public sector services supplied by public administrations, either to one another or to European businesses and citizens" (European Commission, 2010). Three scenarios are described: 1) direct interaction between businesses/citizens and a foreign administration; 2) exchange of information between administrations and businesses or citizens and 3) exchange of information between national administrations and EU institutions.

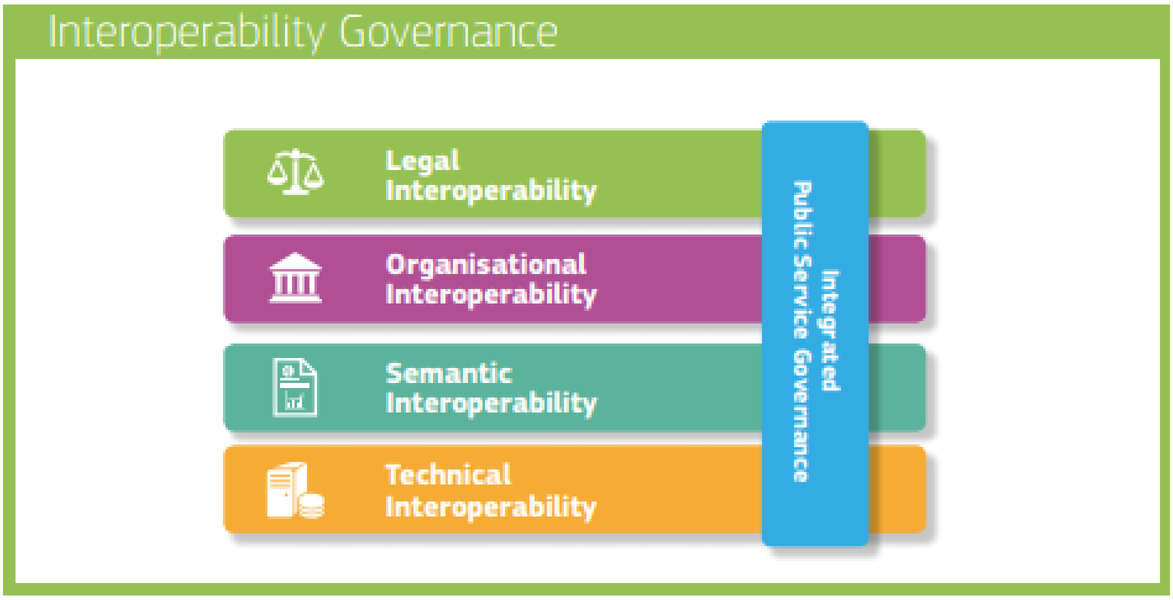
The EIF went through a significant upgrade in 2016/17. The new EIF was formally adopted on 23 March 2017[18]. It introduced, amongst other things, a new concept of Domain Interoperability Frameworks (DIFs). In this respect the geospatial framework offered by EULF, ELISE and INSPIRE is an example of a Domain Interoperability Framework.

The EIF distinguishes four layers of interoperability: legal, organisational, semantic and technical[19], as well as a cross-cutting component of the four layers – Integrated Public Service Governance – and a background layer – Interoperability Governance (see Figure 8). The governance proposals include the setting up of interoperability agreements to work on each of the four levels, based on the 12 underlying principles.

[18] https://ec.europa.eu/isa2/eif_en

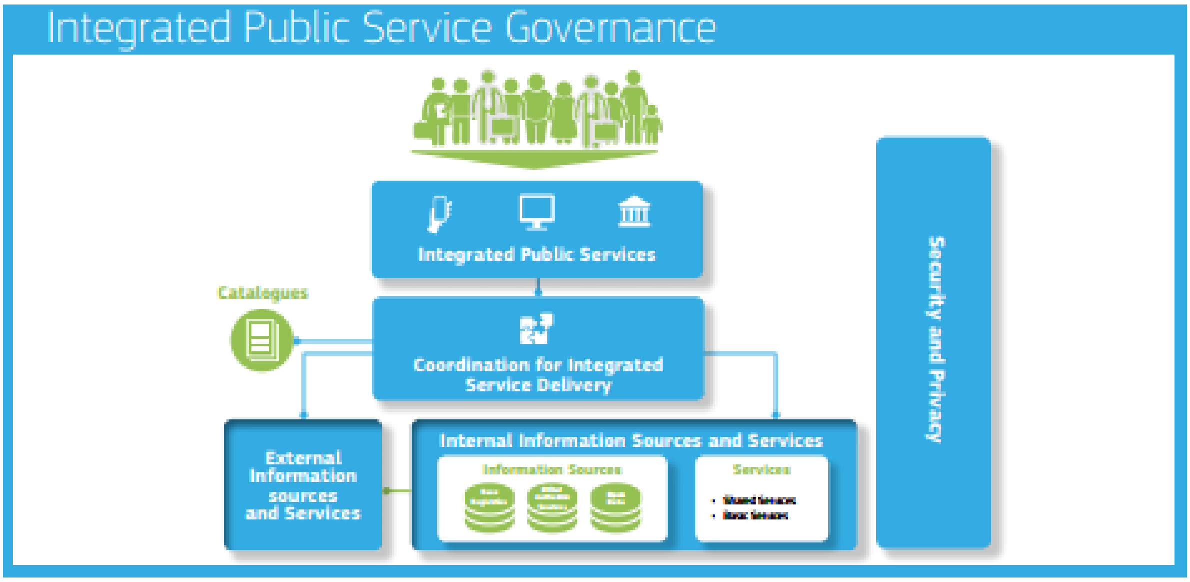
[19] In this document however, the focus is on the topic of architectures and standards, so more on the technological and semantic layers of the EIF. The EIS and EIF are only explained for the sake of completeness.

Figure 10: EIF Interoperability Model (European Commission, 2017)



The EIF also provides an overview of the conceptual model which is the basis of a European Interoperability Architecture (EIA) and European Public Services (see Figure 8).

Figure 11: Conceptual model for integrated public services (European Commission, 2017)



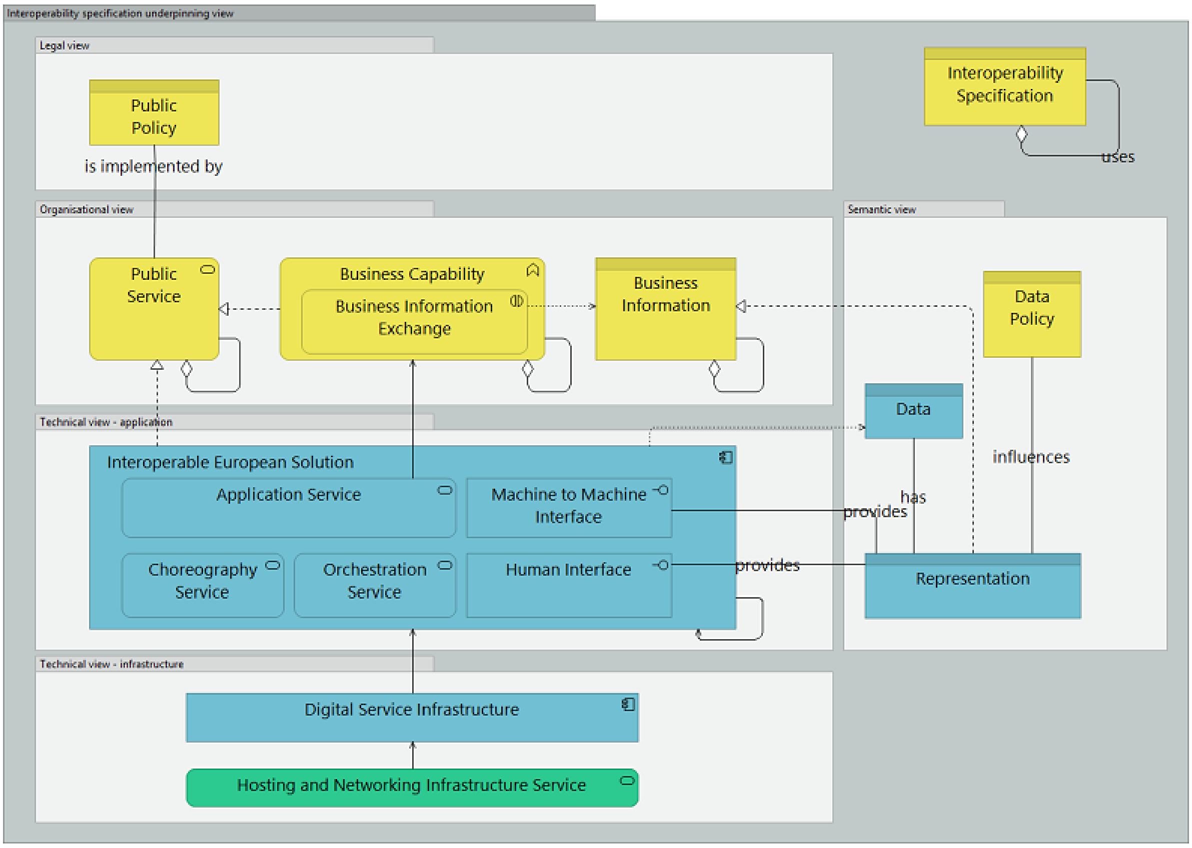
The model promotes the concepts of 'interoperability by design' and 'reusability as a driver for interoperability'. It comprises the following elements:

- 'integrated service delivery' based on a 'coordination function' to remove complexity for the end-user;
- a 'no wrong door' service delivery policy, to provide alternative options and channels for service delivery, while securing the availability of digital channels (digital-by-default);
- reuse of data and services to decrease costs and increase service quality and interoperability;
- catalogues describing reusable services and other assets to increase their findability and usage;
- integrated public service governance;
- security and privacy.

The European Interoperability Architecture (EIA) aims to define a European interoperability architecture facilitating the establishment of European cross-border public services (also called e-Government services). The objectives of the EIA are:

- To elaborate a common vision for an architecture facilitating interoperability for European Public Services;
- To assess the need and the relevance of having common infrastructure services as part of that architecture;
- To define the architecture principles and the conceptual reference architectures.

Figure 12: Schema of the EIRA according to the fours views (ISA, 2016)



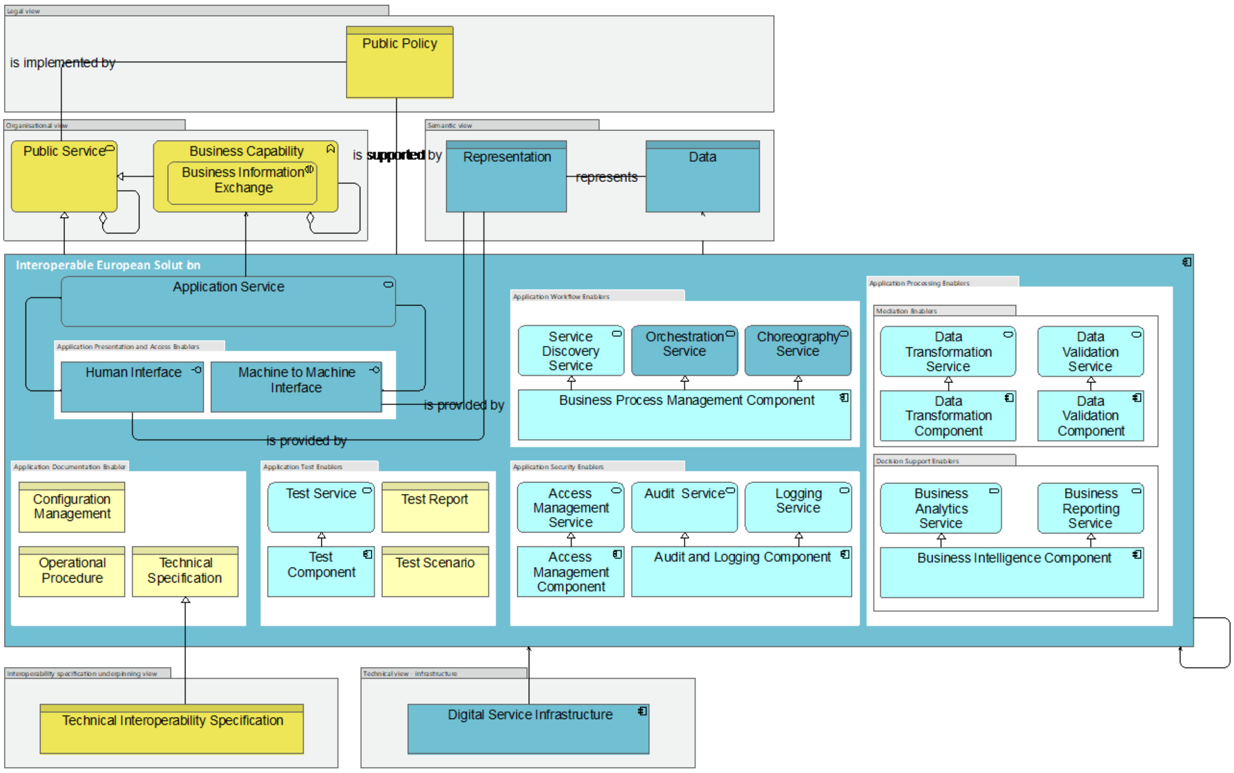
The EIA places emphasis on the development of interoperability agreements to support different solutions.

As part of the EIA, a European Interoperability Reference Architecture (EIRA) has been defined. The EIRA is used for classifying and organising building blocks used in the design and delivery of digital public services. Examples of building blocks are 'organisational policies', 'data models' or 'security enablers'. Member States will use the EIRA to describe in a systematic way: 1) how digital public services are delivered; 2) how the current situation can be improved and 3) how (new) services can be delivered by reusing existing solutions.

The EIRA is composed of four views: the legal view, the organisational view, the semantic view and the technical view (which consist of an application and infrastructure part). Each view contains a set of architecture building blocks, and the relationships between them (see Figure 10). The EIRA building blocks can be mapped against existing solutions. This is done in the European Interoperability Cartography (EIC), which supports the reuse of these solutions.

The example of the generic technical view for applications in Figure 13 shows how a view is composed of different enablers, e.g. workflow enablers, processing enablers and security enablers. For each enabler, there are one or more components: e.g. workflow – business process management component, security – identity and access management component.

Figure 13: The technical view – applications (ISA, 2016)



Although the EIRA embrace all the 4 levels of the EIF, in this document we only focus on the technological and semantic parts, although organisational elements will also be introduced in some cases.

4.2 ICT architectures for SDI and e-Government

A first question to be raised is whether SDI and Digital Government have a real 'own' ICT Architecture. The answer is clearly yes. For several decades, this architecture is for both worlds, the so called Service Oriented Architecture (SOA) consisting of several layers or tiers including data and metadata, registries, web services to access the data and an application tier to search for data (portals) and to use the data.

Several Member States have developed their e-Government architectures according to the principles of the EIF and the views described by the EIRA. A good example is the approach followed by Germany (SAGA 4.0[20]). SAGA stresses the importance of implementing "cross-border e-Government services such as those demanded in the EU services directive" and as described by the first EIF documents[21]. ICT architectures can follow several (combined) implementation options and architecture paradigms (SAGA 4.0). e-Government implementations are usually developed using a component-based approach, and a multi-tier architecture based on service-oriented components. The German architecture follows such a component and SOA-based approach:

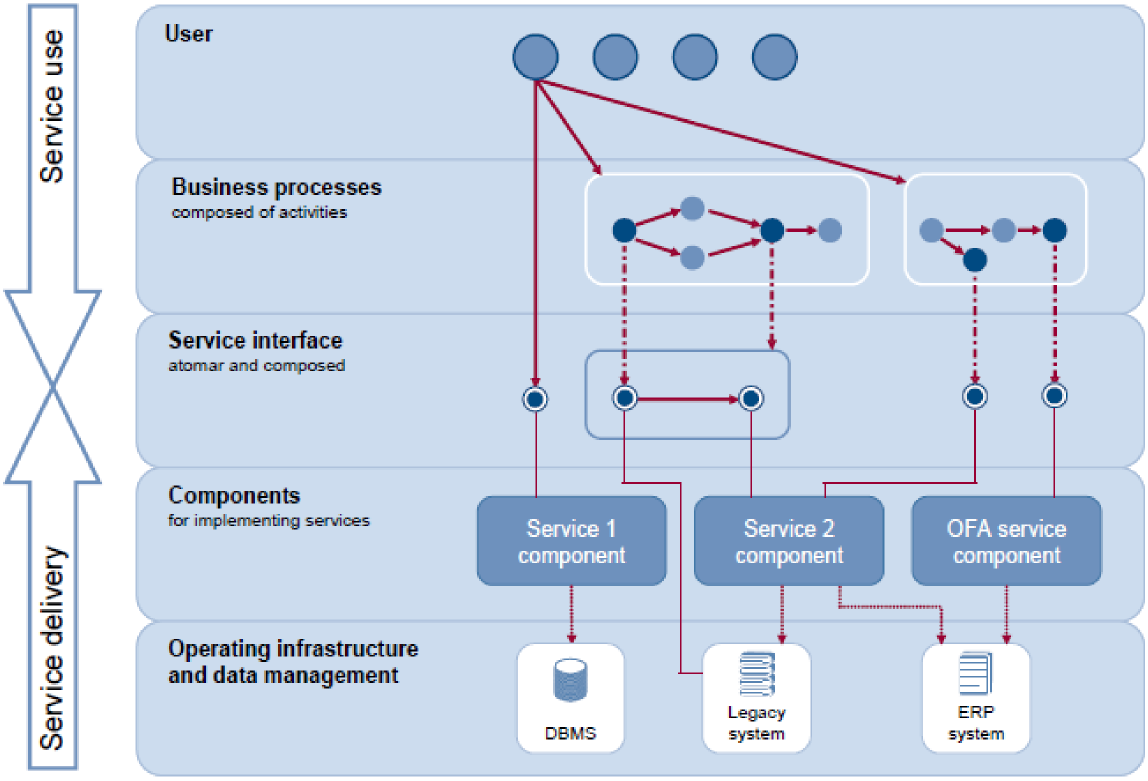
1. Components are entities that are used in software applications and which do not need any modifications in the applications themselves;
2. Services make their functionality available via interfaces; the functionality of newly implemented services is carried out by components; users use the services either directly or integrated into the business processes they run:
   (a) For interaction between services and the users, a communication basis must be defined based on generally accepted standards;
   (b) Potential users which perform activities in the context of specific business processes (see Figure 14), must be able to find and receive information about the services available, and their characteristics.

[20] In the meantime, there is a newer version of SAGA (5.0), but the fundamentals have not been changed.

[21] SAGA 4.0 refers to the European Interoperability Framework for Pan-European e-Government Services" (EIF) v1.0, IDABC, 2004. SAGA 1.1 was already in place in 2003. In fact, the EIF has been developed also based on practices in different Member States.

3. Multi-component, service based multi-tier architecture which separates[22]:
4. Business and data storage logic;
   (a) Presentation and business logic;
   (b) Client and presentation logic.

Figure 14: SOA Reference Model (SAGA 4.0)

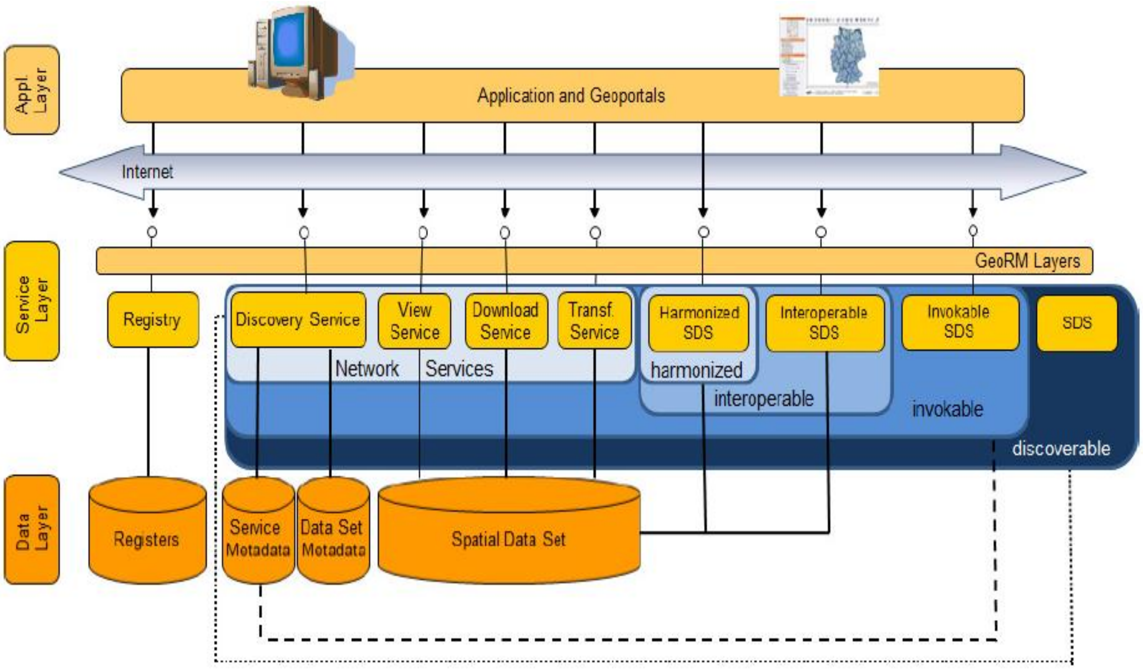


Such architectures offer an optimal solution for managing changes, trouble-shooting, flexibility, reusability and reproducibility. They allow for multiple channel representations towards the client(s) (web access, mobile phones …). A SOA requires close cooperation between ICT, technical staff and business analysts in order to document existing business processes and to identify suitable services that support those business processes.

SDI and INSPIRE architectures fit very well in the general e-Government architectures. For example, the INSPIRE architecture is also a SOA-based architecture and also most of the National SDIs in Europe and elsewhere in the world apply the same design[23]. In the context of SDIs, the three tiers (or layers) are used to expose spatial data (see Figure 15). Web services such as a Web Map Service (WMS) or Web Feature Service (WFS) can be consumed through a geoportal (application) or any other desktop client able to integrate the services. The INSPIRE initiative does not pay much attention to the business processes in which the INSPIRE components might be used. Hence, the importance of adding this aspect into the work of the EULF Blueprint.

[22] Although the presentation tier might be part of the client/application tier.
[23] In some developing countries, an SDI exists, but the service tier might be under developed or not developed at all.

Figure 15: Overview of the architecture of an SDI, the INSPIRE case



The data resources, access services, the metadata describing the data and services, as well as the other components of the infrastructure are entirely based on a series of ISO standards (the ISO 19100 series) and OGC standard interfaces (CEN/TR 15449, 2013). Figure 16 shows the same architecture in a simplified and more generic way with the different semantic and technical standards that apply. Note that specifications and standards are also considered as building blocks in the context of the EIRA.

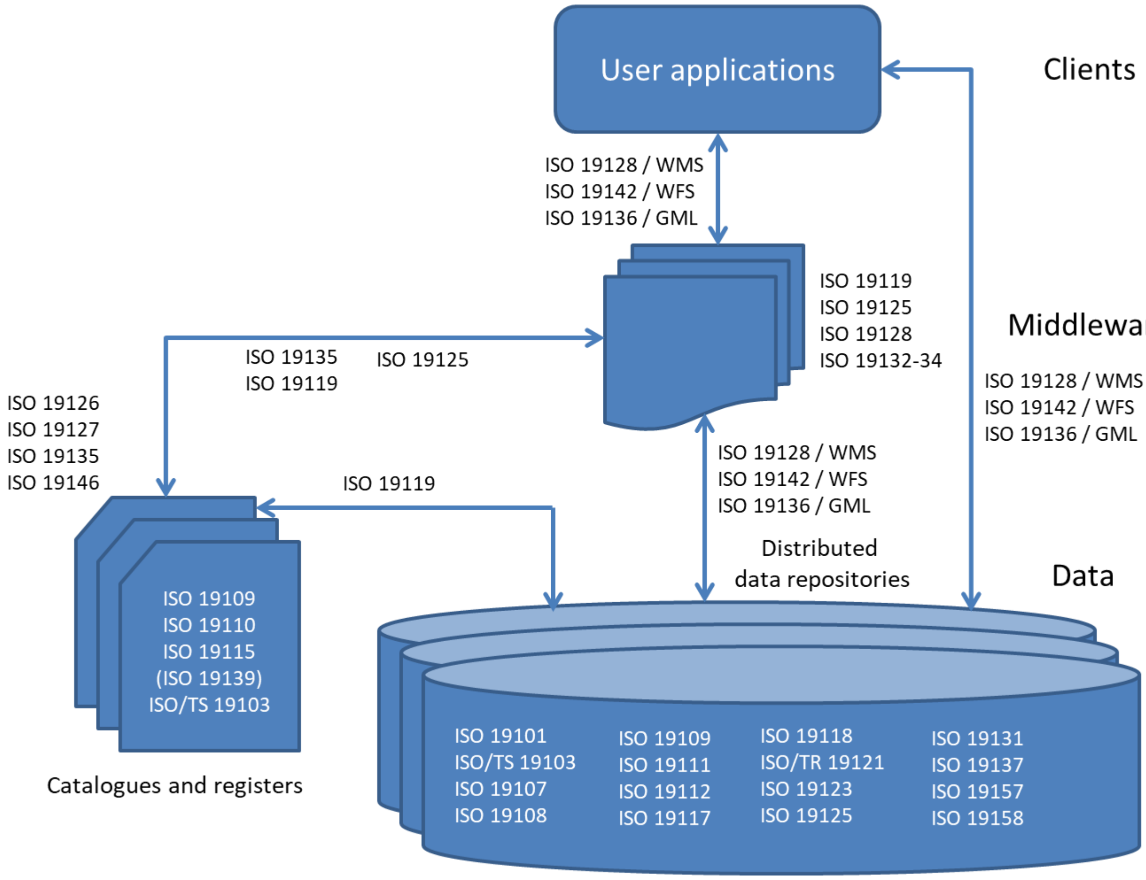
In many SDIs, the Rights Management layer (to guarantee secure access) is not considered.

Over the past 10 years or so, many countries have added another middle tier, i.e. a layer that consists of APIs that support the faster integration of SDI data and services in existing or new applications. This is an important development that facilitates the user uptake of the SDI (components). These developments are described in more detail in section 4.4. Also other related developments such as digital platforms, the role of cloud-fog-edge computing and microservices are believed to influence the 'standard' SDI and e-Government architectures.

Moreover, it should be noted that SDI and e-Government infrastructures are multiple inter-linked networks. They are linked because they harvest one an others catalogues and/or they use common registries, but they are interconnected networks rather than a hierarchical set-up (although for INSPIRE each Member State has some clearly defined tasks).

Finally, the SDI architecture allows other / new components to be integrated or linked to other infrastructures. Examples are the statistical infrastructures ran by Member States and DG ESTAT, or the infrastructures ran by the World Meteorological Organization (WMO), or even private initiatives such as Google Earth and OpenStreetMap. Many, if not most, of existing SDIs already integrate parts of those other infrastructures (e.g. as separate data layers or as part of applications offered).

Figure 16: SDI architecture and most important SDI standards (based on Smits *et al.*, 2002)

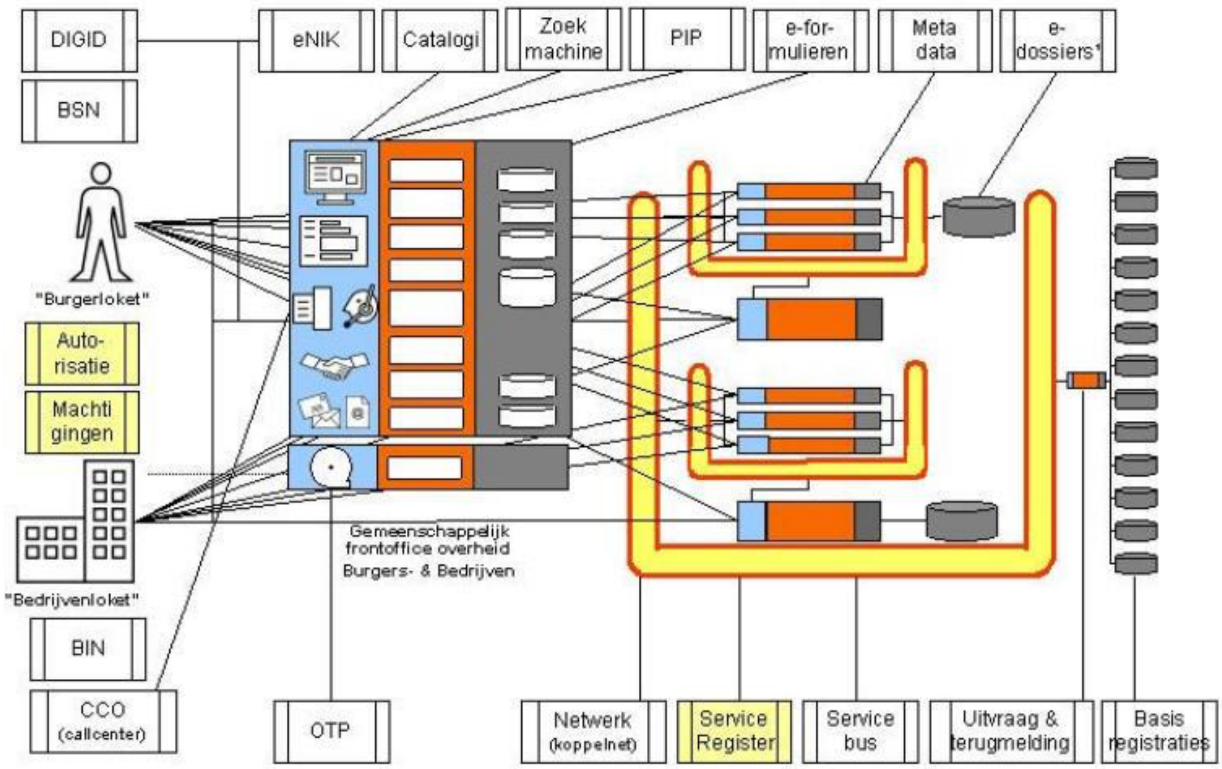


The most relevant standards for SDIs are also listed in annex of this report (technological viewpoint). Figure 17 provides an example of an architecture for e-Government with several of its building blocks and the SDI building blocks that are part of it (The Netherlands, NORA 3.0). It is another example of the implementation of the EIRA, consisting of a series of (re-usable) components such as: e-Government services/applications for citizens, businesses and governments; basic registries; a service bus, etc.

The most important building blocks of the Dutch e-Government architecture are:

1. A series of basic registers with information on citizens (persons), businesses, addresses, (cadastral) parcels, buildings …;
2. Relevant metadata and catalogues;
3. A joint front office of the Government for all citizens and businesses to access several services;
4. A mechanism for unique IDs for citizens (BSN), businesses and organisations (BIN); guaranteeing the digital identity (DIGID);
5. A secured mechanism for citizens to access their information that is stored and updated by Governmental entities through a Personal Internet Page (PIP) and the use of an electronic identity card (eNIK);
6. A series of standard e-forms for exchange of information and e-dossiers for storing that information;
7. A central contact point for Governmental services that can be used by citizen and businesses (CCO);
8. A network and service bus, and a series of services stored and documented in a service register.

Figure 17: Building blocks of the Dutch e-Government architecture (NORA 3.0)



BIN: Business and Organisational Number BSN: Citizens Number CCO: Contact Centre of the Government DIGID: Digital Identity	eNIK: electronic ID Card OTP : Governmental Transaction Port PIP: Personal Internet Page

4.3 Standards for designing ICT architectures

The Open Group Architecture Framework - TOGAF

TOGAF is a framework – an Architecture delivery method and a set of supporting tools - for developing an enterprise architecture. It may be used freely by any organisation wishing to develop an enterprise architecture for use within that organisation. TOGAF is developed and maintained by members of The Open Group, working within the Architecture Forum[24]. The original development of TOGAF in 1995 was based on the Technical Architecture Framework for Information Management (TAFIM), developed by the US Department of Defense (DoD). The DoD gave The Open Group explicit permission and encouragement to create TOGAF by building on the TAFIM, which itself was the result of many years of development effort. Starting from this sound foundation, the members of The Open Group Architecture Forum have developed successive versions of TOGAF and published each one on The Open Group public web site. TOGAF is the framework that has been used to define the European Interoperability Reference Architecture, and also by NORA in the Netherlands.

TOGAF defines "enterprise" as any collection of organisations that has a common set of goals. For example, an enterprise could be a government agency, a whole corporation, a division of a corporation, a single department, or a chain of geographically distant organisations linked together by common ownership. The term "enterprise" in the context of "enterprise architecture" can be used to denote both an entire enterprise - encompassing all of its information and technology services, processes, and infrastructure - and a specific domain within the enterprise. In both cases, the architecture crosses multiple systems, and multiple functional groups within the enterprise. Government agencies may include multiple enterprises, and may develop and maintain a number of independent enterprise architectures to address each one. However, there is often much in common about the information systems in each enterprise, and there is usually great potential to gain in the use of a common architecture framework. For example, a common framework can provide a basis for the development of an Architecture Repository for the integration and re-use of models, designs and baseline data.

[24] www.opengroup.org/architecture

Examples of other frameworks and standards for developing architectures (based on Matthijssen, 2009)

Dynamic Enterprise Architecture (DYA)

A framework, developed by Sogeti, to promote working under one architecture in an organisation. DYA sees the architecture as a process that supports change processes in an organisation. An organisational architecture is only designed when necessary, based on concrete business objectives.

Generalised Enterprise Reference Architecture and Methodology (GERAM)

This methodology recognises several phases in an architectural project: identify the need for an architecture; conceptualise the possible architectures; document the requirements and preconditions; design of the desired architecture with the use of models; implementation of the necessary changes and reporting; operation based on portfolio management; and the decommissioning phase during which new business processes and ICT systems fit the described architecture. GERAM includes a classification of concepts for describing different aspects of the architecture: the human-oriented concept describes actors and their roles; the process-oriented concept described the business processes and the technology oriented concept describes the supporting technology.

Nolan-Norton Framework

This framework is the result of a cooperative research project involving 17 large Dutch companies. The framework is used as a guideline for the process of developing, defining and implementing an architecture in an organisation. It defines five steps: content and objectives based on the existing architecture; architecture development process defining the phases and deliverables; architecture execution process defining the reasons for changing, the required information and responsibilities; architectural competences defining the maturity of the organisation; and cost/benefit considerations.

Zachman Framework

This framework was the first information systems architectural framework, originating in 1987. The framework, which was extended in 1992, is aimed at defining an enterprise-wide architecture for all information systems of an organisation. The Zachman Framework is determined by two aspects: viewpoints and abstractions. The viewpoints are linked to parties that play a particular role in the development of IT systems, defined as rows of a matrix: scope, enterprise model, system model, technology model, representation. The abstractions are questions that can be asked about the viewpoints and are defined as the columns of the matrix: data, function, locations, people, time and motivation.

ISO/IEC 42010:2007

Addresses the activities of the creation, analysis and sustainment of architectures of software-intensive systems, and the recording of such architectures in terms of architectural descriptions. ISO/IEC 42010:2007 establishes a conceptual framework for architectural description and defines the content of an architectural description. ISO/IEC 42010:2007 describes the fundamental organisation of a system in terms of its components, their mutual relations (interactions) and the relations with the environment. Annexes provide the rationale for key concepts and terminology, the relationships to other standards, and examples of usage. ISO/IEC is the successor of IEEE 1471.

Other frameworks include: Gartner Enterprise Architecture Method (GEAM), Integrated Architecture Framework (IAF), and Model-Driven Architecture (MDA).

4.4 New developments

Many technological developments have an impact on how traditional SDIs work. While the focus of SDIs was, and still is to a large extent, to provide mechanisms to publish, search, find and bind geospatial data through web interfaces, supported by metadata catalogues and geoportal applications, new approaches have been developed to make discovery and the use of the data easier. The emergence of dedicated APIs, in general, and in the context of SDIs, in particular, facilitate the development of new and innovative applications. Traditional geoportals, the use of search mechanisms and the access to the data have been proven not to be straightforward for users, nor for developers not very familiar with the geospatial domain (EEA, 2019).

In this section, three important developments are discussed that impact the way in which SDIs are established: APIs, new approaches for publishing spatial data on the web and the availability of new ways of computing using the cloud, the Edge and the Fog. Also the emerging digital platforms which are meant to have more interaction and involvement with the user will have an impact on the traditional geoportals that 'offer' data to user communities.

4.4.1 APIs and microservices

An Application Programming Interface is a set of clearly defined methods to allow a service or other software component to communicate with, and use services and functions from, another software component. In other words, similar to a Graphical User Interface that allows a user to interact with an application, an API allows applications to interact with one another. It can be seen as a contract between components describing how information is exchanged. It is believed that APIs have become a foundational technological component of modern digital architectures and of the digital transformation of government, impacting every sector of the global economy (Santoro et al., 2019). In fact they are not new, but in recent years they have certainly gained importance.

An application developer utilises APIs to build an application by combining various software libraries. With the advent of the Web, the notion of Web APIs was introduced to indicate APIs operating over the Web. APIs separate the internal implementation from the interface. This allows components to be used without knowing the details of their internal implementation. APIs differ from the well-known web service interfaces used in SDIs. Web Service interfaces are designed to offer access to "high-level" functionalities for end users, either humans or machines. On the other hand, APIs are designed to provide even "low-level" functionalities as building blocks that can be used and combined by software developers to deliver a higher-level service (Santoro *et al.*, 2019).

APIs also support modularity; complex systems can be broken down into smaller components connected through APIs. These smaller components are known as microservices. Instead of one monolithic block, an application becomes a network of microservices connected by APIs. Microservices are seen as a new architectural style for APIs, a variant of the more traditional SOA. The idea is that everything is broken down into smaller pieces and then connected (chained, orchestrated).

By reusing APIs, this process improves efficiency and it creates new opportunities, both inside an organisation and externally, across organisations. In the context of Digital Government, Web APIs are especially important. The growing use of digital platforms and Internet of Things (IoT) emphasises the importance of these APIs, as they are used for data exchange between the different components in such distributed systems.

To fulfil their potential, allowing a broad consummation and promoting enhanced interoperability, it is a must that APIs are simple and standardised. Santoro *et al.* (2019) also argue that "in order to get stable APIs for digital government services, there is a need to avoid the adoption of ad hoc solutions and, instead, to rely on a number of existing standards provided by standardisation bodies".

Indeed, APIs are often difficult to use, and programmers repeatedly spend significant time learning new APIs. Complexity also results in incorrect use of the APIs. And according to the OGC, the recent proliferation of APIs for geospatial applications has degraded the interoperability previously established by open standards (OGC, 2017). Therefore, the OGC is taking the initiative to work across disciplines to get the next generation of the standards aligned early in their development and sufficiently modular to maximise their flexibility (Simmons, 2019). Furthermore the implementation of OpenAPI will drive the use of the new OGC APIs. OpenAPI is an API description format for REST APIs allowing the entire API to be described in a format readable to both humans and machines (Swagger website). The OGC is identifying an initial set of OGC Essential Standards to support 'geospatial components for everyone'.

MESH Architectures and Service MESH[25]

A service mesh is a dedicated infrastructure layer that controls service-to-service communication over a network. Service meshes appear commonly in concert with cloud-based applications, containers and microservices. A service mesh is in control of delivering service requests in an application. Common features provided by a service mesh include service discovery, load balancing, encryption and failure recovery. High availability is also common through utilising software controlled by APIs rather than through hardware. Service meshes can make service-to-service communication fast, reliable and secure.

As an example, an application structured in a microservices architecture might be composed of hundreds of services, all with their own instances operating in a live environment. This could make it challenging for developers to keep track of which components must interact, and make changes to their application if something goes wrong. Utilising a service mesh allows developers to separate service-to-service communication into a dedicated layer.

Several European SDI implementations have seen the development of APIs to support the integration of their components in various applications. A good example is the SDI in Flanders, Belgium. The SDI has not only a traditional offer of data, accessible through the geoportal geopunt.be (where users can still search, find and bind data by making use of web services such as WMS, WMTS), but also a series of 14 APIs for developers that allow them to embed some of the SDI components into work processes and applications. There are not only typical APIs to connect to base layers of the SDI, such as CRAB (addresses), the building registry, KLIP (utilities), but also those that provide secure access (Geosecure), and to support image processing work flows (image processing chain). Several private companies have used the APIs to build new applications for, for example, municipalities.

4.4.2 Spatial Data on the Web

The development and exploitation of SDIs have revealed that using them is not as straightforward as one could expect. This is related to the fact that SDIs are mostly based on the (publish)-search-find-bind paradigm. Users are assumed to look for a dataset (or part thereof) through a geoportal by querying the metadata. When getting a response it is not always clear whether it is the data the user is looking for because the incomplete or outdated metadata. It may also become even more difficult to reach the data themselves: there might be a web service for viewing or downloading, but even ICT experts are often not used to these type of services. In addition, users might just need information on a particular object (real-world object or ‘thing’ or dataset object). They might search by using, for example, Google, but how would that be possible using the SDI? Some experimental work has been done in the context of a project of the European Environmental Agency (EEA) “Reportnet and data harvesting using INSPIRE infrastructure” (EEA, 2019a; 2019b), one by data harvesting using INSPIRE network services, the other by Referencing spatial objects by using the INSPIRE network services. It was concluded that the process is not so obvious for various reasons, including the inconsistency in the use of identifiers.

Portele *et al.* (2017) identified several reasons for the difficulties encountered by non-expert users: 1) OGC Web services do not address indexing of their content by search engines; 2) catalogue services only provide access to the metadata; 3) accessing the data requires a user to construct complex queries which requires, in turn, in-depth knowledge of both data structure and the domain-specific query language and 4) the data are difficult to understand since they are often complex themselves. The work proposes some Best Practices to answer the challenges. In total 35 Data on the Web Best Practices (BP) and 13 Spatial Data on the Web are defined. Some of the most pertinent are:

- Use globally unique persistent HTTP URIs for Spatial Things
- Make your spatial data index-able by search engines
- Link resources together to create the Web of data
- Expose spatial data through 'convenience APIs

One of the important outcomes of a workshop discussing ways forward to improve the usability of traditional SDI architectures was to use more common web standards (e.g. de-referenceable http URIs, RESTful APIs and JSON) in addition to, or on top of, the current SDI technologies and standards, as well as to publish spatial data

[25] https://searchitoperations.techtarget.com/definition/service-mesh

in different formats (e.g. CSV, XML, HDF5, JSON and RDF serialisation syntaxes, such as RDF/XML, JSON-LD or Turtle), not only as OGC web services.

The new API standards developed by the OGC are based on the main findings of the Spatial Data on the Web initiative.

4.4.3 Digital platforms and cloud-fog-edge computing

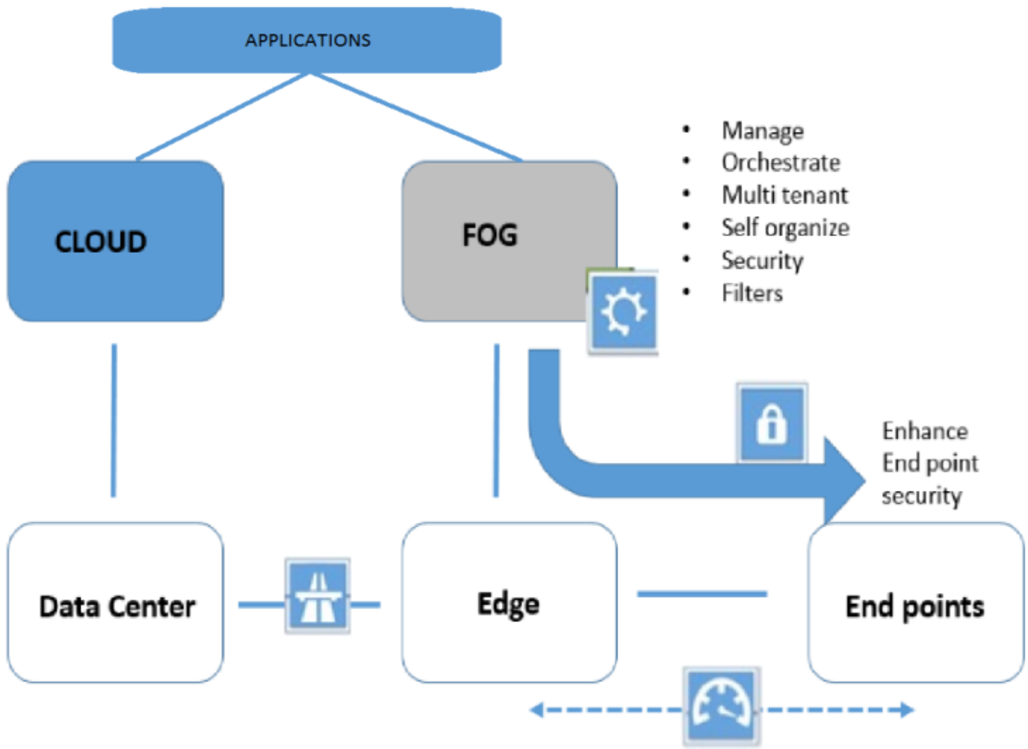
A Digital Platform "is a business-driven framework that allows a community of partners, providers and consumers to share, extend or enhance digital processes and capabilities for the benefit of all stakeholders involved through a common digital technology system" (Moyer, 2016). Over the past decades, digital platforms saw light, mainly in the private sector: e.g. Amazon and Facebook. They are expected to play also a crucial role in the Digital Transformation of Government. Key in the definition is the fact that the platforms brings together different stakeholders from a community, so collaboration is key. This is different from the more 'static' platforms and infrastructures that provide access to data and information, such as the traditional web portals.

According to a study by Gartner, the trend toward Digital Transformation in general and the role of Digital Platforms in particular (public and private) will impact data and knowledge intensive markets (financial services, governments, transportation, etc.). It is suggested that location information and location-enabled services (both public and private) are key components in the majority of Digital Platforms and the importance of location intelligence will reach new heights thanks to the more than 25 billion devices that will be connected to the "Internet of Things" by 2021 of which 5.5 billion will be based in Europe (Gartner, 2018). The same study observes that many platforms do not (yet) use International Standards.

One of the more advanced digital platforms developed by a government is X-road in Estonia. The platform allows various public and private sector e-service information systems to link to each other and to interoperate. It includes a full range of services for the general public. To ensure secure transfers, all outgoing data is digitally signed and encrypted, and all incoming data is authenticated and logged. The data are managed by the respective authorities avoiding duplication of the data.

Another important development relates to the Internet of Things (IoT) which is supported by cloud-edge-fog computing. The latter are changing the way data are managed (centrally/decentralised) and how data is processed. Edge computing is extending data processing to the edge of a network in addition to computing in a cloud or a central data centre (IEC, 2018).

Figure 18: Cloud-edge-fog computing (IEC, 2018)



In Edge and Fog computing the OpenFog Consortium plays a crucial role. Fog architectures selectively move computation, storage, communication, control, and decision-making closer to the network edge where data is being generated in order solve the limitations in current infrastructure to enable mission-critical, data-dense use cases (OGC, 2018). The OGC white paper argues that in order to achieve the "intelligence from data" the computing architecture needs to include elements based on open standards for semantically enriching unstructured Edge data using the concepts of space and time.

Several domain have been identified to apply the approach: smart cities; resource management in precision agriculture; location based services; transportation and moving objects. There exist already a suite of OGC standards to support this, but more needs to be done. Many opportunities and potential use cases are identified in the OGC white paper. One example is to use spatial-temporal concepts applied to observations made by multiple sensors on the edge. Features can be identified and tracked both in edge nodes and in the fog. This can be achieved by applying the concepts of Geospatial Fusion to the Edge Intelligence and OpenFog approaches. The OGC has defined a road map for the potential development of standards (or adaptations to existing standards) to better exploit the cloud-edge-fog computing approach.

4.5 Conclusions

e-Government architectures are typically component and SOA based. Since SDIs and INSPIRE follow the same approach, this means that e-Government architectures can easily integrate location based components such as INSPIRE network services. This also means that in the context of the development of the EIRA, SDI and INSPIRE components could be documented explicitly as part of the interoperable solutions for Europe. Moreover, the frameworks, tools and standards for describing the architectures are quite similar. The RM-ODP usually used in the geospatial world and the EIRA have very similar views to describe the ICT architecture and its components, while several frameworks and standards are available to describe them. New developments have an important impact on the SDI architectures. APIs can be seen as a new layer in the SDI architecture. Many European SDIs have now (geospatial) APIs included. Also, the way we publish geospatial data on the web and the way of searching and using geospatial data is evolving towards a semantic web approach. Finally, the emergence of new digital platforms and new ways of computing allow the data to be decentralised more and more, as is the case in Edge and Fog computing, but with some challenges related to a currently emerging use of standards.

5 Semantic standards for e-Government – Information viewpoint

This section describes the semantic aspects of e-Government and how they relate to assets from SDIs. Firstly, some of the metadata issues are discussed with the Asset Description Metadata Schema (ADMS) and Data Catalogue Vocabulary (DCAT) Application Domain as main initiatives in the ISA/ISA^2 Programme. The relationship with metadata standards for SDIs is explored, while also some examples are given of implementations. Secondly, the core vocabularies are described as key semantic assets for e-Government. Also, here the relationship with semantic data models of SDIs is explored and some examples of implementations are given. This section represents the **information viewpoint** of '*Architectures and Standards for SDI and e-Government*'.

5.1 Metadata

There are many public administrations and service providers that have developed reusable interoperability solutions such as: methodologies, specifications, software, tools and services. However, these solutions are not always (well) documented and they are scattered over many different places. As a result, it is difficult to get an overview of what exists, their characteristics and the conditions under which they can be (re)used. The lack of documentation and oversight is a major barrier to the reuse of interoperability solutions. Several initiatives have been taken in recent years to help solve this problem: the 'Asset Description Metadata Schema (ADMS)' and the 'Data Catalogue Vocabulary – Application Profile (DCAT-AP)' are two of them. Similarly, the SDI world has developed solutions by defining different standards for metadata. This section describes the ADMS and DCAT-AP initiatives and compares them with SDI solutions.

5.1.1 Asset Description Metadata Schema (ADMS)[26]

ADMS is a specification used to describe semantic interoperability assets allowing interested parties to search and discover them. It is also proposed as a schema for describing such assets, i.e. descriptions of assets that can be contained in, and made available through, Semantic Interoperability Asset Repositories. Asset types can vary, including code lists, domain models and schema (e.g. the application schema from INSPIRE), vocabularies and ontologies[27], thesauri and service descriptions, amongst others. ADMS is not aimed at describing e-Government primary data resources such as documents, services, software or datasets. A Semantic Asset Distribution represents a particular physical implementation of a Semantic Asset such as a downloadable computer file that implements the content of an Asset. ADMS itself[28] has two serialisation types associated with it: an RDF schema and an XML schema.

ADMS is intended to facilitate the federation of repositories of interoperability assets. ADMS makes the following possible:

- Solution providers, such as standardisation organisations and public administrations, can describe their interoperability solutions using the standardised descriptive metadata terms of ADMS, while keeping their own system for documenting and storing them;
- Content aggregators, such as JoinUp, can aggregate ADMS descriptions into a single point of access;
- ICT developers can explore, find, identify, select and obtain interoperability solutions from this single point of access.

ADMS is intended as a model that facilitates federation and co-operation. It is not the primary intention that repository publishers redesign or convert their current systems and data to conform to ADMS but, rather, that ADMS can act as a common layer among repositories that want to exchange such information. On the other hand, developers of new repositories, or publishers of existing repositories, can build systems that allow the creation and maintenance of asset descriptions in an ADMS-compliant format. The development process of

[26] The ADMS specification was developed in an International Working Group of more than 60 representatives from public administrations and other experts from 20 EU Member States, following an open and inclusive process of consensus building. The ADMS specification is endorsed by the EU Member States through the Coordination Group of the ISA/ISA^2 Programme.

[27] Vocabularies define the concepts and relationships (also referred to as "terms") used to describe and represent an area of interest. The term ontology is usually used for more complex, and possibly quite formal collections of terms, whereas vocabulary is used when such strict formalism is not necessarily used or only in a very loose sense (W3C, 2016).

[28] http://joinup.ec.europa.eu/asset/adms/release/10

ADMS is based on the methodology for the development of core vocabularies[29]. One of the basic considerations of that methodology is that semantic elements should re-use existing vocabularies where possible.

ADMS has been extended to allow documenting software components. It is called ADMS.SW which is a metadata vocabulary to describe software, making it possible to explore, find, and link software on the Web. The specification extends ADMS and reuses existing specifications such as Description of a Project (DOAP), Software Package Data Exchange (SPDX), ISO 19770-2[30] and the Trove software map. By using ADMS.SW to describe software in repositories and catalogues, publishers increase discoverability and enable applications easily to consume software metadata.

In the context of e-Government, there exist several ADMS implementations. Examples are:

- **JoinUp (European Commission, DG DIGIT)**

  It provides a single-access point to more than 4000 interoperability solutions included in the collections of more than 40 standardisation bodies, public administrations and open source software repositories. The interoperability solutions are described using ADMS-(AP), while the import, export, content management and search features are also based on ADMS-(AP).

- **XRepository[31] (German Federal Ministry of the Interior, KOSIT) includes an ADMS export feature.**

  The main aim of XRepository is to publish specific and general data models for reuse in projects, thus leading to savings and improved interoperability (see figure 19). It also includes code lists and core reusable components, amongst others. In order to obtain a large content base, the obstacles to the inclusion of data models are kept as low as possible. However, this can be opposed when there is a demand for higher quality. Hence, XRepository is set up at several levels.

Figure 19: Standardisation process in Xrepository

29 The methodology is described in the document "Process and methodology for Core Vocabularies": https://joinup.ec.europa.eu/sites/default/files/e7/30/8d/D3.1-Process%20and%20Methodology%20for%20Core%20Vocabularies_v1.01.pdf

30 ISO/IEC 19770 is an international standard about software asset management (SAM), comprising three main parts. Part 2 provides a software asset management data standard for software identification tags.

31 https://www.xrepository.de/

5.1.2 Data Catalogue Vocabulary – Application Profile (DCAT-AP)

Data users may find it difficult to get an overview of which datasets exist and where they can be obtained. When datasets are based in another Member State, language barriers may apply and the structure of government can be unfamiliar. Data publishers, on the other hand, often use *ad hoc* descriptions for their datasets, which results in non-interoperable open data portals. The DCAT Application Profile[32] for data portals (DCAT-AP) provides a solution for this problem. It defines a common specification for describing public sector datasets to enable the exchange of descriptions of datasets among data portals.

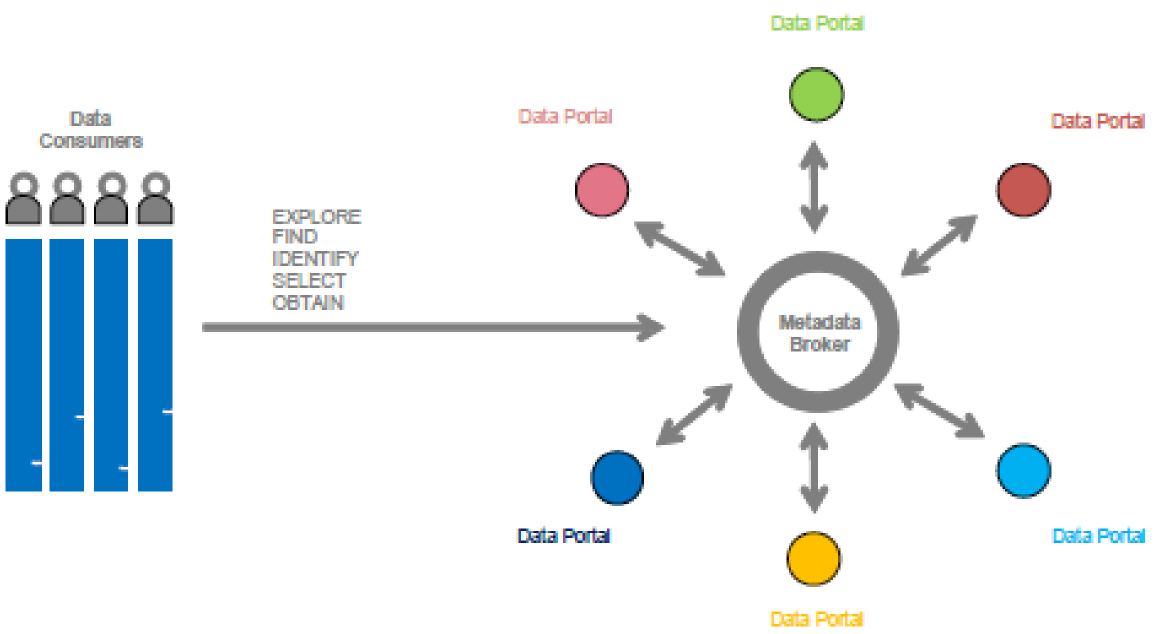
The DCAT-AP makes the following possible:

- Data catalogues can describe their dataset collections using a standardised description, while keeping their own system for documenting and storing them.
- Content aggregators, such as the pan-European data portal, can aggregate such descriptions into a single point of access.
- Data consumers can more easily find datasets from a single point of access.

DCAT-AP was created by a Working Group with representatives from 16 European Member States, based on DCAT which is published by W3C as a recommendation. The work on DCAT was initiated by the Digital Enterprise Research Institute (DERI) and the Greek National Institute for Public Administration and Decentralisation. DCAT is an RDF vocabulary[33] designed to facilitate interoperability between data catalogues published on the Web[34]. Additional classes and properties from other well-known vocabularies are re-used where necessary. The work on the DCAT-AP, therefore, is extending an existing specification. It has the following objectives (as shown in figure 20):

- Identify the essential elements and attributes of DCAT in the European context;
- Identify the controlled vocabularies to be used in the European context; and
- Identify the strict minimum description metadata to be exchanged between data portals in Europe.

Figure 20: Basic use case: enable a search for datasets across various data portals (ISA, 2014)



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32 An Application Profile is a specification that re-uses terms from one or more base standards, adding more specificity by identifying mandatory, recommended and optional elements to be used for a particular application, as well as recommendations for controlled vocabularies to be used.

33 RDF vocabulary metadata/mappings are documented here: https://lov.linkeddata.es/dataset/lov/vocabs/rdf

34 http://www.w3.org/TR/vocab-dcat/

Several interesting implementations of DCAT-AP exist. The DCAT-AP was implemented on the Open Data Interoperability Platform (ODIP) of the Open Data Support service initiated by DG CONNECT of the European Commission. The platform currently contains harmonised descriptions of more than 57,000 datasets from nine data catalogues. The DCAT-AP is also referred to in the Swedish national framework for Open Data as the native representation format for datasets. Other implementations can be found at Member State level. For instance the Austrian Open Government Data Cooperation has developed a DCAT Application Profile called "OGD Metadaten – 2.1". In Spain, the *Norma Técnica de Interoperabilidad de Reutilización de recursos de la información* is an interoperability specification (in Spanish) based on the DCAT vocabulary that defines how Spanish public administrations should describe their datasets, or Public Sector Information (PSI), in general.

In the meantime, a new version of DCAT, on which DCAT-AP was built, has been released: i.e. DCAT v2. It has been developed by the W3C DXWG. It is a major revision of the DCAT v1 vocabulary in response to new use cases, requirements and the experience from the community since its publication. Many changes took place: e.g. an alignment between DCAT and schema.org; more detailed representation of information on quality and provenance of the data; the possibility to describe services and any asset, and not only data sets. It is important to mention that DCAT 2 does not make DCAT v1 implementations obsolete.

5.1.3 Relationship with SDI standards

The question is whether the above-mentioned metadata standards and application profiles are useful for the geospatial community. Indeed, the geospatial community has developed standards to describe metadata of spatial data sets and services, e.g. EN ISO 19115 - Geographic information – Metadata, and EN ISO 19139 - Geographic information - Metadata - XML schema implementation. In the context of INSPIRE, a specification has been developed starting from these international standards (see http://inspire.ec.europa.eu/). Furthermore, work has been done to collect and document key building blocks such as the application schemas and code lists. Registers have been and are being setup for storing and accessing them helping with consistent referencing to, for example, data ranges and specific spatial objects in a feature concept dictionary[35], helping to create harmonised geospatial data across Europe[36]. It would be worthwhile to be able to integrate the metadata collected in the many geospatial catalogues into general governmental (open data) portals in order to make the geospatial data even more visible. Table 3 provides an overview of the relationships between standards and specifications of both the SDI and e-Government communities.

Table 3: Relationships of standards and specifications from SDI and e-Government communities

	ADMS	ADMS-SW	DCAT-AP	ISO/TC 211 standards
e-Government				
Vocabularies, code lists …	✓			Not used
Software and tools		✓		Not used
Data sets			✓	Not used
Geospatial and INSPIRE community				
Registers for application schema, vocabularies, code lists, …	Potentially			EN ISO 19126 ISO/AWI 19164 …

[35] http://inspire.ec.europa.eu/featureconcept

[36] Also in this field, ISO/TC 211 has developed standards: e.g. ISO 19126 - Geographic information -- Feature concept dictionaries and registers and ISO/AWI 19164 – Geographic Information – Registry Service?

Software and tools		Done in the context of ARE3NA		
Data sets			GeoDCAT-AP	EN ISO 19115 EN ISO 19139 INSPIRE IR on metadata ...

While the INSPIRE legal specifications[37], like all EU legal acts, are available through EURLex, the technical guidelines, data models and code lists have been hosted in document and UML repositories, accessible through the INSPIRE Web site (Perego and Lutz, 2014[38]). These INSPIRE components or building blocks can be seen as "interoperability assets", similar to the assets from the e-Government community. In this context, the management and referencing through unique identifiers is a key challenge. The INSPIRE Registry[39], launched in June 2013, is meant to provide solutions to address this issue, taking into account the requirements of the INSPIRE stakeholder community. It is operated according to Linked Data principles, using HTTP URIs as identifiers and implementing content negotiation. Supported register formats are XML, RDF, Atom, JSON, and HTML Moreover, further work is underway to agree on an RDF representation of these registers. The RDF representation used in the INSPIRE Registry (and in the Re3gistry software[40]) is compliant with DCAT-AP – i.e., each register is modelled as a dataset. Version 4 of the INSPIRE Registry includes the following item classes: application schemas, (metadata) code lists, documents, feature concepts, glossary items and themes[41].

The application of Linked Data principles and technology in the e-Government domain shows its potential, also for supporting INSPIRE implementation. It might be seen as a complementary approach for exposing INSPIRE assets providing some flexibility (but adding complexity), rather than the solution for a particular problem in the geospatial domain. Therefore more investigation work is needed in order to collect and describe some good use cases for the use of Linked Data in the context of INSPIRE implementation.

The ability to clearly identify the relevant specifications, as well as their interdependencies, would help ensure a more consistent and cost-effective implementation of INSPIRE. Some experimental work in this area has already been carried out in the context of A Reusable INSPIRE Reference Platform (ARE3NA; ISA Action 1.17[42]), by verifying the suitability of the Asset Description Metadata Schema (ADMS) vocabulary for describing some of the INSPIRE themes. Future work would include the extension to the ADMS vocabulary to describe the context of an asset, concerning both their definition and their actual use (Perego and Lutz, 2014).

Although the geospatial and INSPIRE community have their 'own' metadata standards and specifications, it is worthwhile to verify and test whether a mapping with the DCAT-AP is feasible. With this in mind, extensive (experimental) work has been done in the context of ISA (through a collaboration between the ARE3NA and SEMIC[43] Actions) to develop a geo-profile of DCAT-AP which is called GeoDCAT-AP[44]. GeoDCAT-AP defines RDF bindings for all the INSPIRE metadata elements and for the elements of the core profile of ISO 19115. Therefore, the scope of GeoDCAT-AP is not limited to INSPIRE and the EU, but can be used to provide an RDF representation of ISO 19115 metadata, in general. Rules have been defined in order to transform ISO 19139 records into DCAT-AP[45]. GeoDCAT-AP has been implemented in various portals such as in the INSPIRE portal of the Czech Republic and the European Data Portal. Besides the GeoDCAT-AP profile, other communities have developed profile, including statDCAT-AP for the statistical community and European transportDCAT-AP for the transport domain.

37 The Directive and the corresponding "Implementing Rules"
38 https://www.w3.org/2014/03/lgd/papers/lgd14_submission_62
39 http://inspire.ec.europa.eu/registry/
40 An open source tool for 'reference codes' sharing by anyone: https://joinup.ec.europa.eu/solution/re3gistry
41 https://ies-svn.jrc.ec.europa.eu/projects/registry-development/wiki/RDF_format
42 https://joinup.ec.europa.eu/collection/are3na/about
43 https://joinup.ec.europa.eu/collection/semantic-interoperability-community-semic
44 https://joinup.ec.europa.eu/release/geodcat-ap/v101
45 This is done using XSLT schema. More documentation can be found at https://webgate.ec.europa.eu/CITnet/stash/projects/ODCKAN/repos/iso-19139-to-dcat-ap/browse

5.1.4 Examples of implementations in the geospatial context

ADMS and ADMS.SW have already been used extensively for documenting 'semantic interoperability assets'. Below are some interesting examples, where more can be found on the ISA website.

The Geological Survey of Austria (GBA) – Thesaurus

The GBA thesaurus[46] is a bilingual (DE/EN) controlled vocabulary for the semantic harmonisation of geo-scientific map-based geospatial data. Currently there are four thematic subjects: lithology, geologic timescale, geologic units, and tectonic units and classification. The GBA thesaurus vocabulary is used to create semantically and technically interoperable geospatial datasets to implement the legal requirements of the EU directive 2007/2/EC (INSPIRE). Therefore GBA datasets are coded with thesaurus URI's, and on the other hand the thesaurus is linked to INSPIRE registry codes or other Linked Data vocabularies. The GBA thesaurus is formatted as SKOS concepts (terms, including synonyms), each with their own URI. It is published on the web according to standards of the Semantic Web: Linked Data, RDF, SKOS and SPARQL Endpoints. It is managed and supervised by an editorial team, with experts in various domains.

ARE3NA: INSPIRE interoperability assets – Guidelines repository

Working with other Actions in the Interoperability Solutions for European Public Administrations (ISA) Programme, including work on the Asset Description Metadata Schema (ADMS) and European Federated Interoperability Repository (EFIR), the INSPIRE and ARE3NA teams have looked into ways of registering components of INSPIRE for other communities to use through a federated repository[47]. This has included providing metadata about the semantic assets associated with the INSPIRE Annex I themes, namely: Coordinate reference systems, Geographical grid systems, Geographical names, Administrative units, Addresses, Cadastral parcels, Transport networks, Hydrography and Protected sites[48].

Java4Inspire – toolkit

Java4inspire[49] is a java library to handle INSPIRE data sets as java objects. The target audience are all GIS java programmers looking to provide easy access to INSPIRE data. These users may be:

- spatial data producers: Java4inspire may be used to transform existing spatial datasets into INSPIRE compliant datasets (the module eurostat2inspire shows an example for the EUROSTAT datasets, e.g. NUTS and Urban Audit). Java4inspire provides tools to import external data as java objects, transform them according to the target INSPIRE specifications, and encode them in INSPIRE GML files.
- spatial data users: Java4inspire provides an easy way to parse INSPIRE GML objects into java objects and manipulate them with the common GIS java libraries. It uses binding classes representing INSPIRE feature types automatically built with JAXB.

CSW GeoDCAT-AP implementations

An API has been designed by the JRC to show how GeoDCAT-AP can be implemented in a catalogue service for the web (CSW), by using the standard CSW interface specified by the OGC. In several Member States, including Germany and the Czech Republic, work has been done to implement GeoDCAT-AP as part of their (INSPIRE) catalogue implementations. Also the CKAN community, which develops open source data catalogue software that powers many Open Data portals, is trying to implement DCAT-AP and GeoDCAT-AP as part of its proposed solutions.

5.2 Data

The exchange of information in the context of European Public Services is challenging and comes potentially with many semantic interoperability conflicts. Such interoperability conflicts are caused by discrepancies in the interpretation of administrative procedures and legislation, the lack of commonly agreed data models, the absence of universal reference data and different licensing conditions, amongst others.

46 https://joinup.ec.europa.eu/catalogue/repository/gba-thesaurus
47 https://joinup.ec.europa.eu/catalogue/repository
48 https://joinup.ec.europa.eu/collection/inspire
49 https://joinup.ec.europa.eu/software/java4inspire/home

5.2.1 Core vocabularies: persons, businesses, location and public service

Core vocabularies are semantic assets of the EIRA. They are simplified, re-usable, and extensible data models that capture the fundamental characteristics of an entity in a context-neutral fashion (ISA, 2014). Currently, six Core Vocabularies have been defined: person, business, location and public service, criterion and evidence, and public organisation. The Core Business Vocabulary has been formally published on the W3C standards track. It has been revised and renamed as the Registered Organisation Vocabulary (RegOrg).

Core **Person**: captures the fundamental characteristics of a person, e.g. the name, the gender, the date of birth, the location.

Registered **Organisation** (often referred to as Core **Business**): captures the fundamental characteristics of a legal entity (e.g. its identifier, activities) which is created through a formal registration process, typically in a national or regional register.

Core **Location**: captures the fundamental characteristics of a location, represented as an address, a geographic name or geometry.

Core **Public service**: captures the fundamental characteristics of a service offered by a public administration.

Core **Criterion and evidence**: captures the fundamental characteristics principles and means a private organisation needs to fulfill to be qualified to perform public services.

Core **Public Organisation**: captures the fundamental characteristics describing public organisations in the European Union.

Public administrations can use and extend the Core Vocabularies in different ways:

- Development of new systems: the Core Vocabularies can be used as a starting point for designing the conceptual and logical data models in those new systems.
- Information exchange between systems: the Core Vocabularies can become the basis of a context-specific data model used to exchange data among existing information systems.
- Data integration: the Core Vocabularies can be used to integrate data that comes from disparate data sources and create a data mash-up.
- Open data publishing: the Core Vocabularies can be used as the foundation of a common export format for data in base registries like cadastres, business registers and service portals.

In 2013, five pilots were carried out in collaboration with public administrations in several EU Member States. The pilots were intended as a proof-of-concept to demonstrate the applicability of the Core Vocabularies:

- Pilot on interconnecting Belgian national and regional address registers by making use of the Core Location Vocabulary to publish and connect data from the address registers of the three Belgian regions.
- Pilot on linking organisation data from the public sector using the Organisation vocabulary to describe the organogram of the Greek Ministry of Administrative Reform and e-Governance.
- Pilot on describing public services only once: uses the Core Public Service Vocabulary to create uniform descriptions of public services for the e-CODEX large-scale pilot, the Flemish Intergovernmental Product and Service Catalogue and the Irish Citizens Information portal.
- Pilot on integrating maritime surveillance data using a Linked Data approach to integrate distinct sources of maritime surveillance data based on the Core Location Vocabulary.
- Plant Protection Products Pilot integrating data from eight Member States about applications and decisions concerning the authorisation of plant protection products by companies described using the Registered Organisation Vocabulary.

Several implementations have also seen light in Member States. We provide one example below.

Open Standards for Linking Governments - OSLO

The Open Standards for Linking Governments in Flanders (OSLO) project has developed local extensions of the Registered Organisation, Core Person, Core Location and Core Public Service vocabularies created at European level. The Flemish Government is using the extension of Core Public Service Vocabulary to publish its intergovernmental product and service catalogue as Linked Data. The extensions allow a standardised approach, but taking into account local flavours. Publishing the catalogues a linked data allow users to link information regarding public services to other information on the web, e.g. information regarding Real Estate.

5.2.2 Relationship between SDI and e-Government standards

The e-Government world follows a trend to use vocabularies as metadata on the web (e.g. FOAF, SKOS, Dublin Core, schema.org). Hence, definitions have been agreed regarding fundamental concepts. These concepts are called Core Concepts. They are simplified data models that capture the minimal, global characteristics/attributes of an entity in a generic, country and domain neutral fashion. They are represented as Core Vocabularies using different formalisms (e.g. XML, RDF, JSON).

On the other hand, SDIs and INSPIRE also model the world (based on definitions of concepts), but are doing this differently. SDIs and INSPIRE in particular, are focusing on addressing the interoperability of geospatial data sets and services through the creation of data models (using UML) and geospatial encodings mechanisms (using GML), for the exchange of data related to, for example, one of the 34 spatial data themes defined in the INSPIRE Directive. The semantics are described as part of the UML model.

Work has been done and is ongoing to transform data from one world to the other (from UML application schemas to RDF)[50] [51].

5.2.3 Example of the use of vocabularies and the mapping to GI specifications

In this section we summarise the findings of one of the pilots in which Core Vocabularies were used to integrate spatial data sources and transform data from one data model to the other, i.e. the Core Location Pilot *"Interconnecting Belgian National and Regional Address Data" (Colas, 2013)*.

Address data are created, collected and used by many different stakeholders. This is no different in Belgium where the pilot took place. Different specifications and collections exist: the Agency for Geographic Information (AGIV) developed the CRAB specification and register for the Flemish Region, the IT Centre for the Brussels Region (CIRB) developed and manages the Brussels URBIS system including address data, the Civil Register contains addresses of natural persons, while there is also a Belgian standard in preparation called 'BeSt Add'[52].

Access to, integration and use of address data is, therefore, cumbersome due to this address data fragmentation, the heterogeneous data formats and the lack of common identifiers (Colas *et al.*, 2013). The pilot developed a solution to address these issues based on the following (see Figure 21):

- A set of URIs, enabling Belgian addresses and/or streets to be uniquely identified and looked up on the Web by well-formed HTTP URIs;
- The use of the Core Location RDF vocabulary and experimental INSPIRE RDF vocabularies;
- A linked data infrastructure allowing querying homogenised Belgian address from a SPARQL endpoint.
- The use of simple Web-based standards such as HTTP, XML, and RDF.

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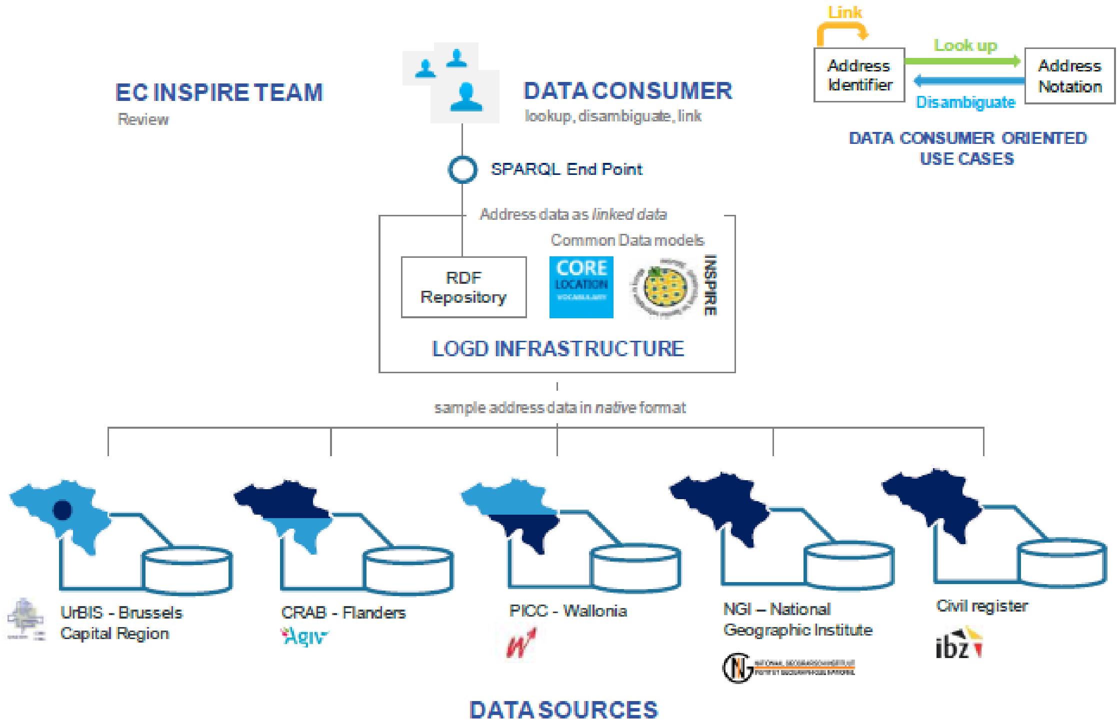
50 ARE3NA – RDF&PID: State of Play; ARE3NA – RDF&PID: Persistent Identifiers Governance; ARE3NA – RDF & PID: Guidelines on methodologies for the creation of RDF vocabularies representing the INSPIRE data models and the transformation of INSPIRE data into RDF.

51 https://github.com/inspire-eu-rdf/inspire-rdf-guidelines

52 https://overheid.vlaanderen.be/crab-belgie-best-add (in Dutch)

Figure 21: Use of the Core Location Vocabulary to integrate address data (Colas *et al.* 2013)



Although not all the issues related to address data have been solved, the pilot demonstrated that (Colas *et al*, 2013):

- The Core Location RDF Vocabulary can be used as a foundational RDF Vocabulary to harmonise address data that originate from disparate organisations and systems;
- The Core Location RDF vocabulary can be extended in a flexible way with experimental INSPIRE RDF vocabularies (i.e. transport networks and administrative units);
- HTTP URI sets can be derived from INSPIRE Unique Object Identifiers for address data, allowing the creation of harmonised Web identifiers for spatial things and spatial objects such as addresses;
- A linked data infrastructure can provide access to harmonised, linked, and enriched location data using standard Web-based interfaces (such as HTTP and SPARQL) and Web-based languages (such as XHTML, RDF+XML), on top of either:
  - existing relational/spatial database systems, by applying database-to-RDF conversions, or;
  - existing INSPIRE XML data, by applying XSLTs to automatically generate RDF, starting from XML-encoded INSPIRE-compliant metadata/data;
- The use of standard Web interfaces (such as HTTP(S) and SPARQL) can simplify the use of location data for both humans and machines.

The pilot is considered a proof-of-concept. Further analysis is needed: on the scalability of the data infrastructures; the management of the data and metadata lifecycle; and the extendibility and configurability of the solution.

5.3 New developments

5.3.1 Extending SDI data models

SDIs – and INSPIRE is not different from that perspective – are usually defining their data sets and series according to models that are made explicit by using a conceptual modelling languages. Many spatial data products follow a strict application schema and have a formal description of the spatial objects in an object catalogues. Common data specifications are very useful, allowing a common language to be spoken and to describe/document all the details of what can be found in a dataset. At the same time, fixing a data model might miss particular needs. In practice, different communities adapt (existing) data models to meet particular data needs.

Therefore, over the past few years, one could see the emergence of extended data models, i.e. adaptations to existing standard schemas. This was often also driven by requirements imposed or pushed by developments in (European) legislation. Examples for reporting directives where data requirements are imposed include the Air Quality Directive, the Marine Strategy Framework Directive and the Noise Directive. National legislation also often requires standardisation. As an example, the new Spatial Planning Act in the Netherlands mandates interoperability. In these cases, the SDI (INSPIRE) baseline data models can be seen as a starting point or a sub-set of usually richer data models. The European Location Framework (ELF) project investigated the need for extended INSPIRE models[53] which resulted in the so-called ELF Data Model. In the context of the same project, an interesting methodology have been proposed and adopted which can be applied to any domain (model).

The EEA, in the context of its monitoring and reporting obligations and with its EIONET membership, has done a lot of work with regard to the extension of (INSPIRE) data models.

Also ISO/TC 211 has dedicated more efforts over the past years on specific extended data models. Examples are in the field of land administration (ISO 19152), addresses (ISO 19160) and classification systems, including Land Cover (ISO 19144).

5.3.2 Big Data and Big Data analytics

It is an understatement that we live an age of abundant data. More data was generated in the last two years than in the entire human history before that. Through Google alone, we submit 40,000 search queries per second. That amounts to 1.2 trillion searches yearly. YouTube has more than 1 billion gigabytes of data on its servers. People share more than 100 terabytes of data on Facebook daily (hostingtribunal.com). According to Statista, the current number of smartphone users in the world today is 3.5 billion. These generate a massive amounts of data (photo's, video's …) including location information.

Geospatial data has been Big Data for decades (OGC, 2017). For example, the Copernicus Programme, with over 12 TB of Earth Observation (EO) data generated daily, is the third largest data provider globally. Another example: in the context of urban monitoring in Tokyo, the locations of one million people are collected every minute which results in up to 1.4 billion records per day.

The term 'Big Data' often refers to data which, due to their volume, exceed the capacity of traditional software to process data within an acceptable time and at an acceptable cost. Big Data as an umbrella term was coined first by Doug McLaney and IBM several years ago to denote data with the following characteristics (known as the "four V's"):

- Volume – the sheer size of "data at rest";
- Velocity – the speed of new data arriving ("data at move");
- Variety – the many different formats, structures and data types; and
- Veracity – trustworthiness and provenance (OGC, 2017).

Gartner defines Big Data as high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision-making, and process automation (Gartner, 2020).

The geospatial sector, and OGC in particular, pays much attention to the Big Data challenge. In different areas, Big Data and Big Data analytics are at the core of the activities. Among the core contributors to the 'data deluge'

53 http://inspire-extensions.wetransform.to/models/2016/04/19/elf-data-model.html

are spatio-temporal sensors, imagery, simulations, and statistics (OGC, 2014). Sensors became ubiquitous: the systematic collection of their data output is currently generating substantial new markets in many sectors. Remote Sensing imagery is utilised in more and more research, business, and societal applications. Climate Modelling and Numerical Weather Prediction data volumes are other examples. In statistics, multi-dimensional data cubes are a common scheme for analysing complex correlations (OGC, 2014). More is expected with the development of the Internet of Things (IoT) and the availability of more intelligent ways of streaming, processing and storing data (see also section 4). Related to Big Data analytics is the concept of location intelligence, seen as "the collection and analysis of many sources of geospatial and other data that are transformed into strategic insights to solve a variety of business challenges"[54]. In this context, also the (geospatial) modelling[55], simulation and prediction efforts should be mentioned (it is one of the emerging topics followed by the OGC).

Several sectors are leading the way, always involving a location component, such as: Earth Observation, resource management in agriculture (precision farming), transportation and monitoring moving objects, mobile location-based services (ITS - Intelligent Transport Systems) and smart cities. From a technology development perspective, there is high commonality of use cases and associated requirements across the different application domains described above. The OGC has defined several possible use cases for geospatial Big Data developments. They are similar to, and build further upon, the reference architecture developed by ISO/IEC JTC 1/WG 9 – Information technology – Big Data[56] : ISO/IEC 20546 Information technology – Big data – Overview and vocabulary and ISO/IEC 20547 Information Technology – Big data Reference architecture (5 Parts).

- Part 1: (TR) Framework and Application Process
- Part 2: (TR) Use Cases and Derived Requirements
- Part 3: (IS) Reference Architecture
- Part 4: (IS) Security and Privacy Fabric (under SC 27/WG 4/5)
- Part 5: (TR) Standards Roadmap

The use cases defined by the OGC are the following: collect & ingest; prepare & structure; analyse & visualise; and model & predict. Based on the first white paper from 2017, a roadmap for Big Data and Big Data analytics have been developed as part of the Technology Trends Watch (see figure 22). The Road Maps are used to decide on areas to perform standardisation work, including priorities. These are then tackled in one or more testbeds and/or pilots. The Road Maps start from two series of questions:

What?

Where do we want to go?; Where are we now?; and How do we get there?

Why?

Why do we need to act?; What should we do?; and How should we do it?

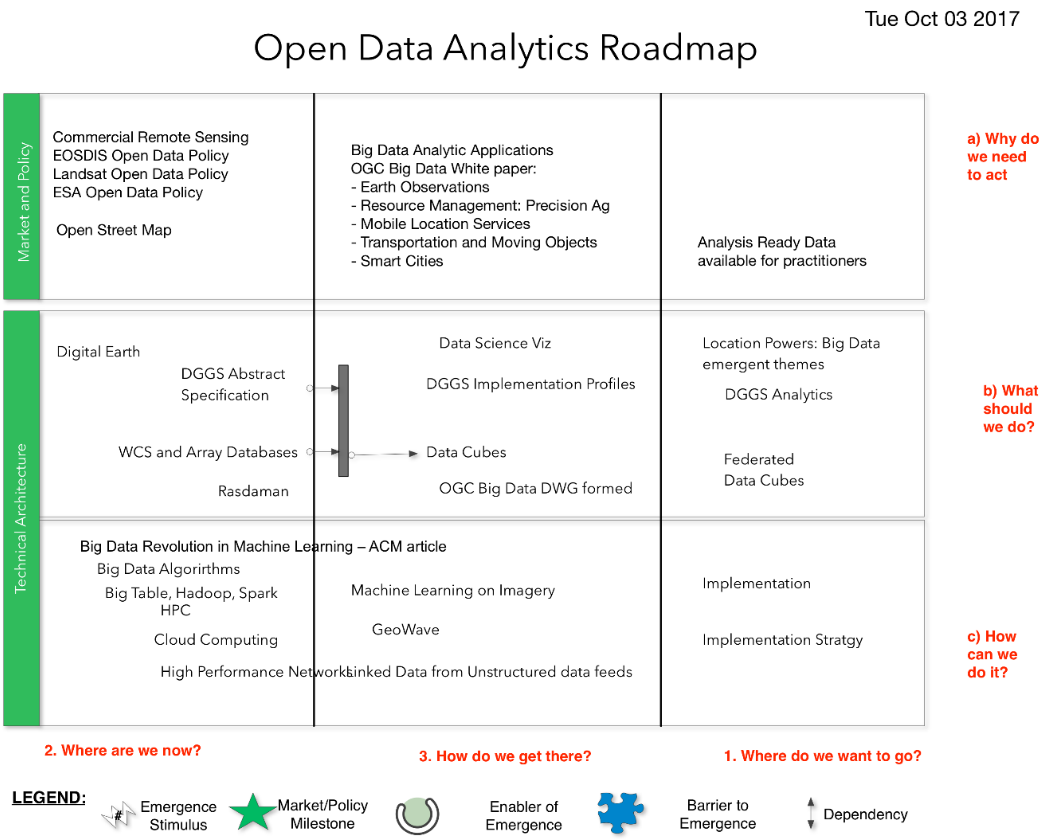
Many different technologies and methods can be used, including: text and graph analytics; spatio-temporal analytics; machine learning; modelling, simulation and prediction; and data fusion and conflation analytics.

54 https://www.geoblink.com/what-is-location-intelligence/

55 A particular type of modelling is agent-based modelling, e.g. the spatial behaviour of children in traffic.

56 WG 9 has been disbanded. With the establishment of SC 42, JTC 1 transferred the JTC 1/WG 9 program of work to SC 42 "Artificial Intelligence" (Resolution 13 of JTC 1 Plenary 2017)

Figure 22: Example Road Map of OGC – Data Analytics (OGC, 2017)



5.3.3 Data archiving and preservation

Archiving and preservation of data resources is not a specific challenge for the geospatial world, nor is it for the e-Government world, on the contrary. It is a general point of attention for any sector handling an ever larger amount of digital data and information. Archiving is about many things. One can talk about a real archiving business process: delivery (pre-ingest), acquisition (ingest), archive processing, preservation, administration, access, consultation and exchange (Segura *et al.*, 2018). Several aspects need to be considered: metadata and documentation; long-term preservation format; secure storage on a platform; importing and exporting facilities … (Završnik, 2019). It is, therefore, not surprising that many communities and standardisation bodies are active in the field and that they are seeking synergies and building upon each other's standards and technical solutions to tackle the challenge. The fact that there are ever bigger amounts of digital data makes the archiving even more challenging, but also more relevant.

The ISA² Programme runs a dedicated Action (2017.01) since 2017 to facilitate archive management across Europe. The action prepared a study to identify existing data standards in archival information management and exploring IT tools and services that can support practical implementations in different contexts. The second part of the action deals with the analysis of requirements for interoperability between the Archives Portal Europe, Europeana, and the Historical Archives of the European Union[57], on the one hand, and the Historical Archives of the European Commission on the other. The Action developed some tools for assessing and benchmarking IT solutions for archives management and is currently conducting some pilots to demonstrate those solutions.

All activities regarding e-Archiving are building further upon one of the European Research Projects, E-ARK. The research project brought together European National Archives and commercial system providers. It developed a pan-European methodology and created seven pilots to define and test the main steps of archives management for digital archives and combining existing national and international best practices[58]. E-ARK focused its work on the provision of technical specifications and tools, the development of an integrated

[57] Run by the European University Institute
[58] http://www.eark-project.com/

archiving infrastructure, the demonstration of improved availability, access and use, and the rigorous analysis of aggregated sets of archival data (Segura *et al*., 2018). In the context of the CEF-Digital Programme, and building further on E-ARK, an operational building block was developed that can be re-used in different technological settings: eArchiving[59]. Several implementations exist in Member States using this building block for digital archiving, as found in Denmark and Slovenia.

Many other archiving initiatives exists that follow the path of standardisation, e.g. the Open Archive Initiative (OAI) that promotes broad access to digital resources for eScholarship, eLearning and eScience.

ISO has developed the standard ISO 14721:2012 — Open Archival Information System (OAIS) Reference model – through its ISO/TC 20/SC 13 for space data and information transfer systems. The model provides a framework for archive management, defining a series of responsibilities and working methods, amongst others: defining terminology and concepts for describing and comparing architectures and operations of existing and future archives; identifying different long-term preservation strategies and techniques; describing elements and processes for long-term digital information preservation and access; providing a basis for comparing the data models of digital information preserved by archives and for discussing how data models and the underlying information may change over time; etc. A key concept of data archiving is the Information Package (IP).

The OAIS Reference Model has also been applied in the geospatial sector through the ISO/TC 211 committee. The ISO 19165-1 standard defines the requirements for the long-term preservation of digital geospatial data. These data also include metadata, representation information, provenance, context and any other content items that capture the knowledge that is necessary to fully understand and reuse the archived data. The standard also refers to characteristics of data formats that are useful for the purpose of archiving. Geospatial data are preserved as a geospatial information package (IP). A geospatial archival IP is fully self-describing and allows a future reconstruction of the dataset without external documentation. A new part of the standard is currently under development, i.e. ISO/FDIS 19165-2 Content specifications for Earth observation data and derived digital products, focusing on EO data. ISO 19165 complements standards developed by ISO/TC 211 such as the ISO 19115 standard for describing metadata.

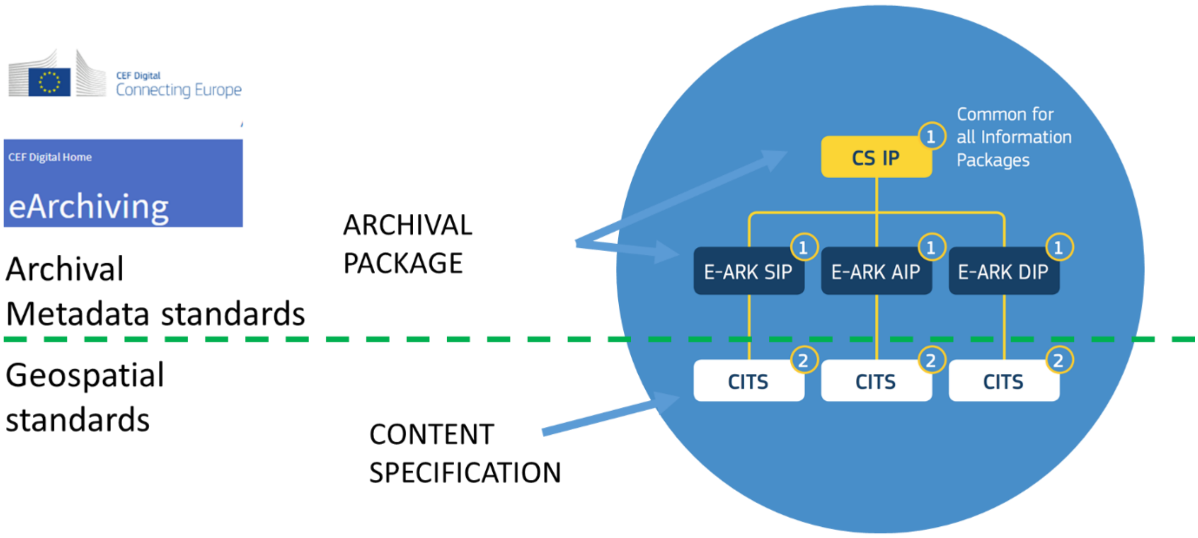
The OGC Data Preservation Domain Working Group (DP-DWG) has discussed over the past years the implementation of geospatial Data Archival solutions based on international standards. The main discussions relate to how geospatial data can be packaged and what should be included since archiving is going beyond metadata descriptions (Završnik, 2019; Maso, 2019). Maso describes the experience of the Catalan Mapping Agency, the ICGC[60], and argues that a standardised approach by making use of Open Packaging Convention (OPC) prescribed by the ISO 19165 standard is key. OPC can be used without any modification for encapsulating geospatial data and metadata by mapping the OAIS concepts and the ones defined by this standard into the OPC concepts (Maso, 2019). The packaging of geospatial data is challenging (many files are making up a geospatial dataset) but possible. It follows a ZIP or TAR file type of approach.

Another example of an Archiving implementation is in Slovenia. A similar approach has been applied based on an Archival Information Package making use of E-ARK components (see figure 23).

[59] https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/eArchiving

[60] Institut Cartogràfic i Geològic de Catalunya

Figure 23: Use of eArchiving based on E-ARK for Archival Packaging (Završnik, 2019)



For archiving, several metadata standards are used: METS – Metadata Encoding and Transmission Standard (Packet structure), the PREMIS[61] Metadata Dictionary (Provenance and Change history) and EAD - Encoded Archival Description - a standard for encoding descriptive information regarding archival records (Content description). The archival package also contains the data (multiple representations – GML being proposed as long-term archiving format), technical documentation such as attribute definitions, feature catalogue, common queries and geo-processing workflows, as well as contextual information such as legal background and project documentation (Završnik, 2019). The conclusion is that combining geospatial metadata standards and archiving standards allows the archiving and preservation challenge to be addressed.

5.4 Conclusions

Many semantic standards for e-Government have been developed based on basic standards from e.g. W3C. They cover metadata and data: DCAT has been extended to DCAT-AP to address specific European requirements for exchanging information from catalogues, while the GeoDCAT-AP profile has in turn built further on DCAT-AP to covering specific requirements from the geospatial and INSPIRE communities. Also ADMS has been used for e.g. documenting INSPIRE assets such as tools, code lists, etc. Other work has explored the transformation between INSPIRE data specifications such as addresses and the ISA Core Location Vocabulary. All this work has proven that the exchange of assets between the geospatial and e-Government world is possible, although not necessarily straightforward. This opens up new opportunities and will make the integration of location information within e-Government more feasible and easier. In general, there is an interest from the geospatial communities within the Member States to provide their data and metadata not only through INSPIRE services, but also as linked data to enhance their exposure on the web and opening up new ways of using them. In this sense, the application of e-Government semantic standards is complementary to the geospatial standards and INSPIRE approach. New developments in extending core geospatial data models to specific application contexts is a good example of sharing and reuse of semantic assets and has seen several pilots recently in Europe, including those combining SDI and e-government resources. Geospatial data, by its nature is Big Data, and more so when we consider its spatio-temporal dimensions and that applications will often involve drawing inferences from several datasets in the same geographical extent, with Earth Observation, remote sensing and sensor data being key examples generating large amounts of data daily. Related to this volume and a desire to explore change over time, standards and technologies for archiving data, especially in the public sector are receiving increased attention, including e-government building blocks being made available through CEF-digital for all data.

[61] PREservation Metadata: Implementation Strategies Working Group.

Lastly, is worth noting that there are also some technologies requiring further exploration from both the geospatial/SDI and e-government domains, perhaps pointing to some areas of collaboration. For example, 'Location Intelligence' is somewhat ingrained in spatial analysis but it is being brought to the fore by the emergence of digital platforms and the possibilities to apply more business intelligence thinking to strategic problems from a geospatial perspective. This topic links well with discussions of digital transformation when appropriate technologies should also be considered, along with their related standards. Artificial Intelligence is also receiving much attention and ongoing work in the JRC through the AI Watch initiative[62] is also exploring its broad impacts, including on government. Lastly, as already highlighted by the OGC in their technology trends watch, digital twins may be an area worth exploring as they offer "a mirror image of a physical process that is articulated alongside the process in question, usually matching exactly the operation of the physical process which takes place in real time" Batty (2018; after Grieves, 2014). As shown above, the process perspective is worth considering from the point of view of data-centricity in government, the role geospatial data can play and, again, issues related to the digital transformation of government.

[62] https://ec.europa.eu/knowledge4policy/ai-watch_en

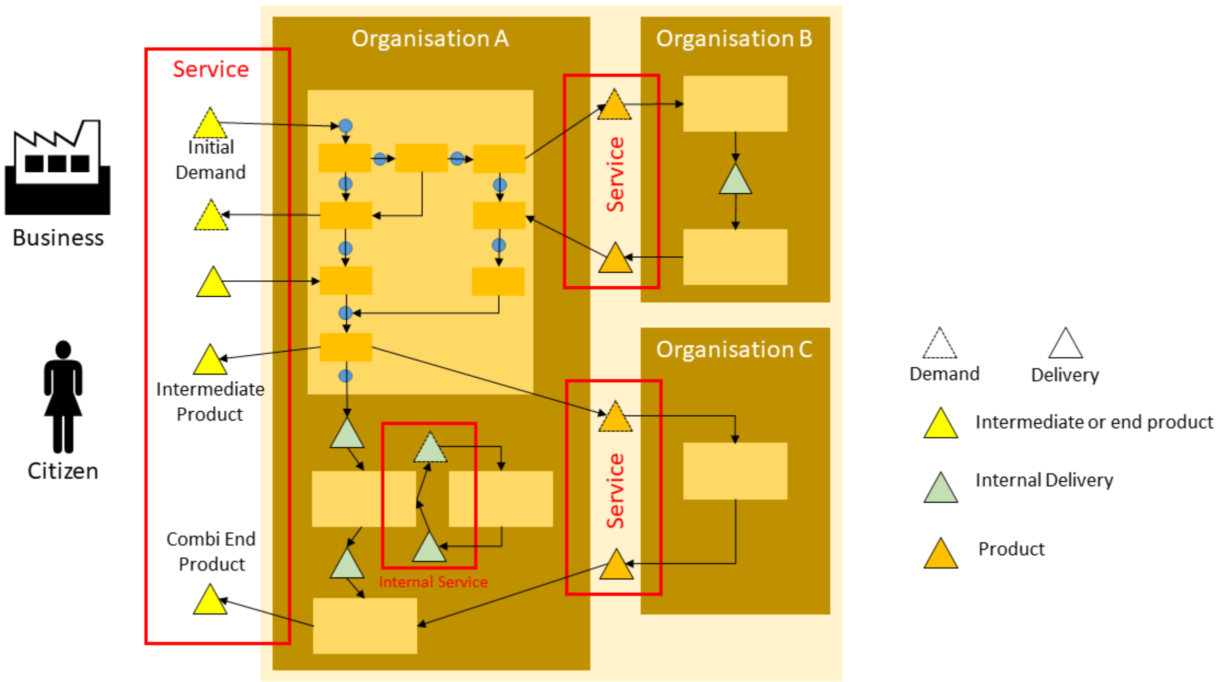
6 Services for e-Government – Computational viewpoint

This section describes the services for running business processes. The way in which services steer the process and link to each other for doing so is explained. The relationship with SDI services is also explained, while in a last sub-section some examples of combining SDI and e-Government services are given. This section represents the **computational viewpoint** of *'Architectures and Standards for SDI and e-Government'*.

6.1 Business process services and management

Services are key in any operational business process. In practice, many services might be necessary to cover all the process steps. They use certain data / information, process them and deliver an output in the form of a document, figure, map, etc. While data services only provide access to, or deliver, data in a certain format, business process services are used to process the data to generate new data/information.

Figure 24: Link between services and business processes (NORA 3.0, 2012)



Processes are carried out by different actors (human beings, but also machines) in order to deliver a product or service. A public administration delivers the product or service to a citizen, a business or another public administration. In practice, several administrations might be involved. So, for example a public body might rely on services delivered by one or more other public bodies. The citizen or business that receives the product or service will not see these different process steps.

The example in Figure 24 illustrates a case where three organisations are involved: A, B and C. It is organisation A that delivers the service to the citizen. The service consists of different products: an intermediate and an end product, e.g. a temporary building permit and final building permit. Organisations B and C deliver a service to organisation A. For example, organisation B might provide the necessary information about the person (citizen) involved, while organisation C might deliver the cadastral parcel information.

The cooperation between the public administrations A, B and C requires steering of the overall process and its sub-processes. Three major roles can be distinguished: the delivery of the service to the 'client', the steering of the process and sub-processes and the execution of the process. Generally speaking, there are three ways of dividing the different roles:

- The organisation that delivers service (A) is responsible for the whole chain of the different sub-processes. Organisation (A) will connect to all sub-contractors to obtain certain services (e.g. information on a person) and will deliver the final result of the service to the citizen/business (e.g. a building permit). This is the principle of 'main contractor' and 'subcontractor' (which is shown in figure 25);

- The organisation that delivers service (A) hands over the responsibility for (parts of) the processes that are executed by other organisations (B & C) to those organisations. In this case, for example, organisation (A) connects to organisation (B) which, in turn, might connect to organisation (C). Organisation (C) might even deliver the results of the service to the citizen/business. This is called the relay principle;
- All the organisations involved define and setup together a steering process that is coordinated by one entity, organisation (A). One of the organisations involved might have the task to deliver the results of the service to the citizen/business. This is called the principle of central steering.

In this context, service chaining and orchestration are important concepts[63]. Orchestration describes the automated arrangement, coordination, and management of complex computer systems, middleware, and services. It has been applied in Interoperability Experiments of the OGC to automate data flows and interconnect the services required for data access and processing (see section 6.2). Service chaining is the process of combining or pipelining results from several complementary (GIS) Web Services to create customised applications (Alameh, 2003). This has also been applied in the context of OGC activities (Percival, 2006). Typically SDI services are services to access the spatial data, but also specific interfaces to process data exist and can be combined (e.g. the Web Processing Service of the OGC). A typical process in the context of SDIs is the search-find-bind process which allows the user to search for specific data, (pre-)view the data and download it to bind it in a particular application. Service chaining would then allow this process to be 'automated', i.e. to access one service after the other from within the same application.

6.2 Examples of integrating SDI and business services

One of the examples of the integration of SDI and business services can be found in the Open Geospatial Consortium Interoperability Programme (Arctur, 2011). OGC organises Interoperability Experiments and testbeds to test and validate OGC Web Services, often in combination with other services. The OGC Web Services Initiative, Phase 8 (OWS-8) was carried out in 2011 with 40 organisations[64] actively involved, and 43 software components (servers, clients and other applications). OWS-8 was organised around 4 threads:

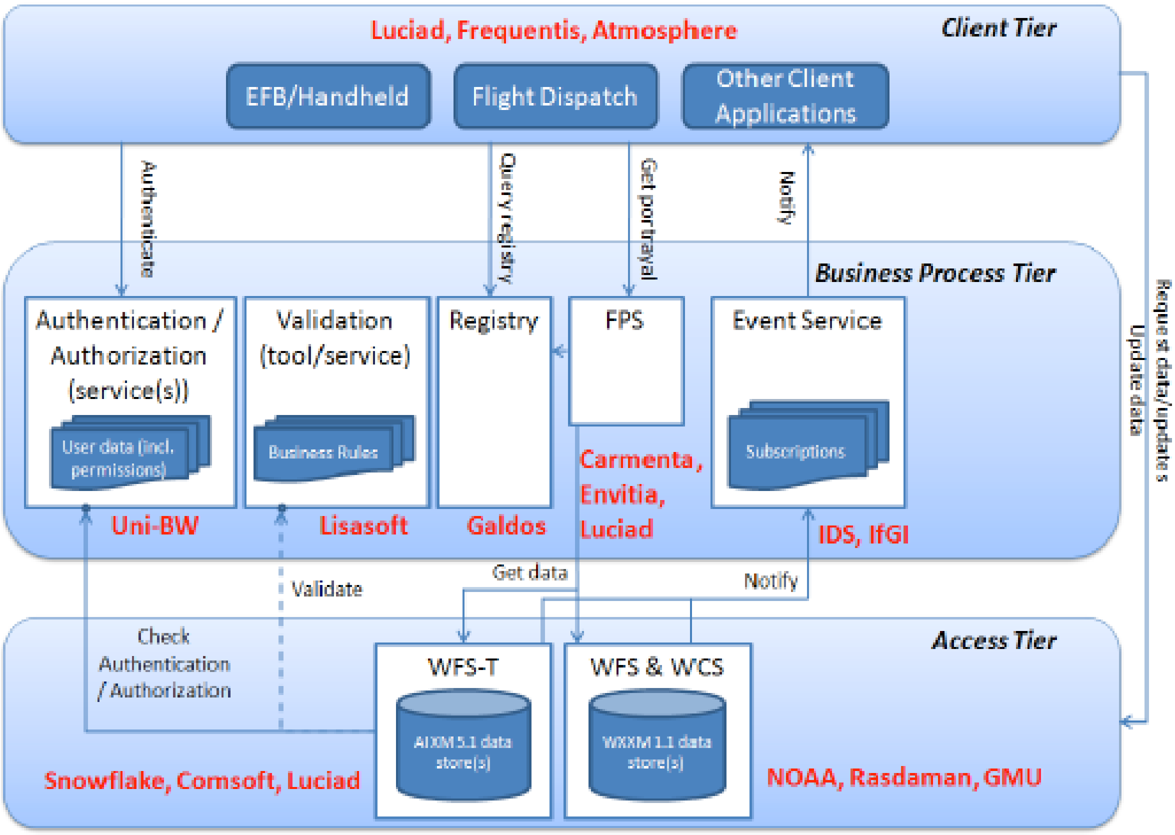
- Aviation;
- Cross-Community Interoperability;
- Geosyncronisation and Geodata bulk Transfer;
- Observation Fusion (coverages and tracking).

Figure 25 provides an overview of the overall architecture including several SDI building blocks, as well as 'regular' ICT building blocks. The access tier consisted of transactional WFS (WFS-T), and regular WFS and WCS. The business process tier provided an event service (based on meteorological data), authentication/authorisation service, validation services, etc. Different applications were tested in the client tier.

63 Sometimes the term choreography is used.

64 Including, among others, 52North, Lockheed Martin, NASA, Luciad, Eurocontrol, Compusult, ATOS, ESA, ESRI, Interactive Instruments and many others. This and more recent examples of completed initiatives can be found on the OGC Website: https://www.ogc.org/projects/initiatives/completed

Figure 25: OWS-8 Aviation Architecture Diagram (Arctur, 2011)

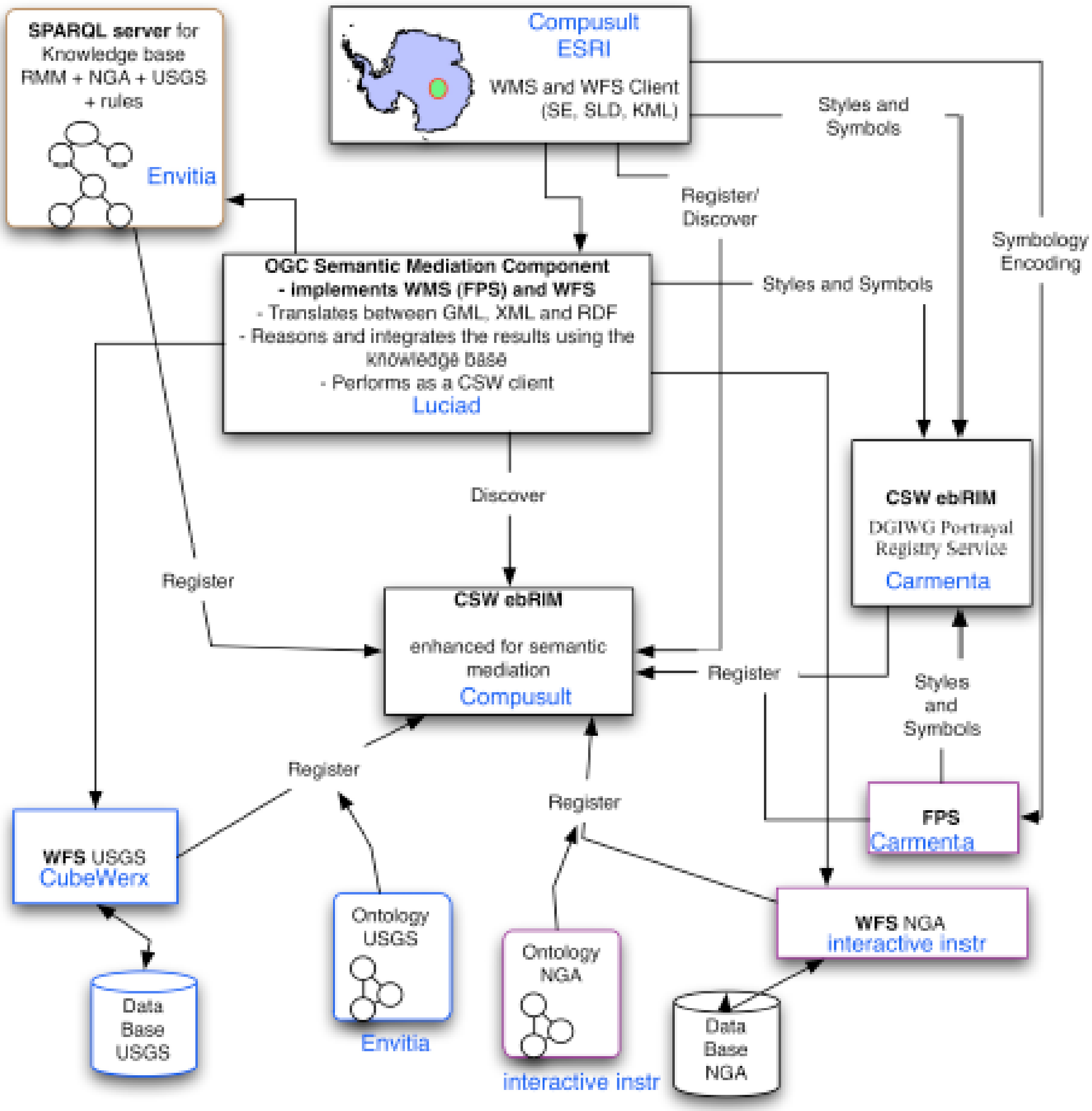


One of the challenges was to resolve the semantic interoperability issues 'on-the-fly' by building them into a process steered by a mediator or central coordinator (see section 6.1). Many aspects were tested and progress was made towards a more integrated approach. Some of the aspects tackled were:

- Advancement of semantic mediation approaches to deal with differences in heterogeneous data models using Semantic Web technologies (e.g. ontologies, RDF, SKOS) and, at the same time enabling machines to share specifications of concepts and, thus, be able to interpret, harmonise and convert information consistently.
- Advancement of the use of portrayal: style registries and services focusing on the DGWIG (Defence Geospatial Information Working Group of the USA) portrayal registry including the creation of enhanced custom Styled Layer Descriptors (SLDs) based on catalogue discovery of features and Web Feature Services.
- Advancement of Schema Automation transforming domain models from UML to GML with support for ISO 19115 metadata profiles and the development of OCL-to-Schematron encoding rule extensions to support the ISO/TS 19139 and the proposed GML 3.3 encoding.
- Implementation of a prototype "Semantic Mediation Service" that wraps a WFS into a user-preferred Feature Model and implementation of a knowledge base SPARQL service.
- Development of Rosetta Mediation Models for mapping between USGS and NGA data models.
- Enhancement of the open source ShapeChange UML conversion tool to support automated creation of RDF/OWL, Codelists (SKOS), KML (XSLT), GML (XML Schemas), Codelists (GML), Constraints (Schematron).

Figure 26 illustrates how the Semantic mediation component works.

Figure 26: OWS-8 CCI Mediation / Portrayal Architecture Diagram (Arctur, 2011)



6.3 New developments

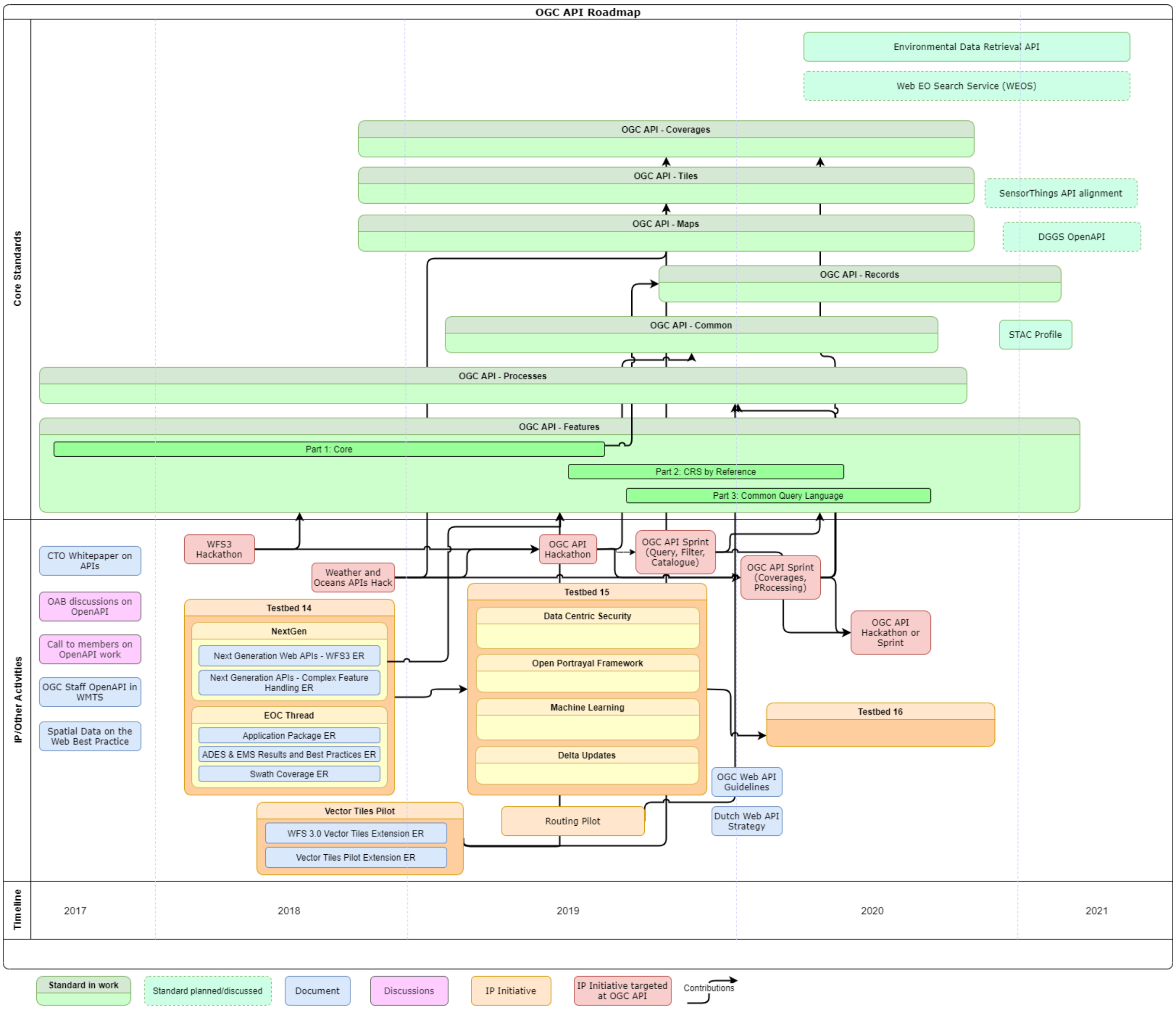
SDIs and e-Government infrastructures have been using Service Oriented Architecture to access resources, combine/process data and integrated them in applications. Discussions in standardisation bodies, especially the OGC have led to a totally new approach for handling data access and for sharing data resources. Focus become more and more on the individual ‘things’, or ‘features’ (or ‘objects’), rather than data sets which are at the core of SDIs.

These developments are of course also related to other technological developments such as the Internet of Things, the fact that we have more and more ‘life’ or ‘event’ data (see also section 3).

OGC is currently building a series of so called OGC APIs which will gradually complement the existing web services and their related standards (WMS, WFS, WCS, WPS …). In fact, the APIs are building on the legacy of those standards (OGC, 2020). The OGC APIs are resource-centric APIs that take advantage of modern web development practices as promoted by, among others, the W3C.

The new series of standards are being constructed as "building blocks" that can be used to develop new APIs for web access to geospatial content. The building blocks are defined not only by the requirements of the specific standards, but also by prototyping and testing their interoperability in the OGC Innovation Program. OGC has prepared a Roadmap of the current and planned standardisation efforts with this respect, as well as related extensions to those standards (see figure 27).

Figure 27: OGC API Roadmap (OGC, 2020)



Currently, a candidate standard, called OGC API-Common has been submitted for public comment. Indeed, while developing some of the new OGC API standards, some elements proved to be common across all OGC API standards. The candidate standard identifies resources, captures compliance classes, and specifies requirements that are applicable to all OGC API standards. It will be submitted at least for public comments in two cycles since it has to be implemented in several OGC API standards for testing its completeness and robustness. One central standard will be the OGC API – Features standard, originally called WFS 3.0. The first part is ready and is called 'Core'. Two other parts will be developed: CRS and Common Query language. New standards that are planned (see figure 27) are: OGC API Processes, OGC API Maps, OGC API Tiles, and OGC API Coverage, with more planned to follow. One of the other, new developments is the OGC SensorThings API which is a central component for making the link to IoT.

It is planned that a subset of the OGC API series of standards will become ISO standards as well, as was the case for WMS and WFS.

6.3.1 OGC API Features and other related standards

APIs are also being considered to offer access to discrete information, such as the details of a specific protected site in a larger data set. In particular, the access to, and use of, features (objects) will be supported by the new OGC API – Features standard. Features refer to the representations in data resources referring to 'real' world physical objects or 'virtual' objects. The OGC API - Features standards provides API building blocks to create, modify and query features on the Web. Part 1 - Core specifies the core capabilities and is restricted to fetching features where geometries are represented in the coordinate reference system WGS 84 with axis order longitude/latitude. Additional capabilities that address more advanced needs will be specified in additional parts.

Examples include supporting the creation and modification of features, more complex data models, richer queries, additional coordinate reference systems, multiple datasets and collection hierarchies.

The standard has been developed based on basic concepts and practices of the Web: W3C Data on the Web and the W3C/OGC Spatial Data on the Web Best Practices, but also IETF HTTP/HTTPS RFCs and the specific OGC Web API Guidelines. In this context, for example, the concepts of datasets and dataset distributions has already been applied. A client, GIS or web application can discover the APIs' capabilities and retrieve information about this distribution of the dataset, including the API definition and metadata about the feature collections provided by the API. Moreover, it can generate queries to retrieve features from the underlying data store based on simple selection criteria, defined by the same client.

The API will allow more flexible and easier ways to interact with data and will facilitate the automation of complex data flows in the context of work processes.

6.3.2 Sensors Web and SensorThings API

Building upon earlier developments related to Sensor Web Enablement (SWE) activities of OGC, more work is now being done to connect sensors with IoT developments. The OGC SensorThings API provides an open, geospatial-enabled and unified way to interconnect the Internet of Things (IoT) devices, data, and applications over the Web. At a high level, the OGC SensorThings API provides two main functionalities and each function is described in a separate part of the standard. The two parts are the Sensing part (link to the existing Sensor Observation Service standard) and the Tasking part (linked to the existing Sensor Planning Service standard). The Sensing part provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems. The Tasking part is planned as a future work activity and will be defined in a separate document as the Part II of the SensorThings API. It is based on REST principles, JSON encoding, Open Data protocols and URL.

The tasking part is currently under development and is particularly of interest in the context of automating processes and workflows in the context of Digital Governments. A key idea is that 'things' – individual sensors, mobile and wearable devices, drones, *in situ* platforms … - can become task-able and controlled[65].

The SensorThings API should be seen as part of other developments, such as event streaming and the use of the fog-edge computing, amongst others.

6.4 Conclusions

e-Government services delivered to citizens, business and governmental bodies can become very powerful if they support a broad range of business processes and their interactions. Service delivery can be organised in a flexible way, i.e. the different sub-processes / activities can be split in several services and delivered by various organisations. There are different models to steer this process and their sub-processes: from central steering, to relaying and to sub-contracting.

The example provided shows that this process-oriented approach has already been applied in the geospatial community. Indeed, in the context of the OGC Interoperability Programme (OWS-8, OGC Web Services Initiative Phase 8) work has been done to 'automate' and orchestrate complex data (spatial) flows through OGC Web Services. Both (secure) access to the data and semantic data harmonisation have been automated in this context by using a mediation service. This goes beyond the 'simple' set-up of OGC services to be used within a process by a single application (e.g. WMS), as its focus is on the organisation and automation of the process itself.

The example shows the direction to take: i.e. to analyse existing processes and design new processes for e-Government in which the geospatial data and processing are embedded. In some contexts, the adoption of such an approach, alongside an increased emphasis placed on geospatial data and services, may be a form of the digital transformation of government, or at least a key component thereof.

Recent developments for delivering, accessing and using spatial features (things) make it easier for users and developers alike. Rather than using geoportals for searching, finding and binding spatial datasets, the OGC API for features will facilitate the search for, access to and usage of single features which is not so obvious in current SDI set-ups. Also the OGC SensorThings API shows how data flows coming from different devices (sensors, mobiles, drones …) can be more easily integrated in work processes.

[65] They are called actuators. They contain information and metadata about the task-able actuator.

7 Relevant SDI and e-Government standards – Technological viewpoint

This annex provides a comprehensive overview of the relevant standards that are frequently applied in SDI and e-Government implementations. The overview is certainly not exhaustive and ideally might become available as an online repository of standards. For completeness, some elements previously discussed are briefly reintroduced in this section. This list represents the **technical viewpoint** of 'Architectures and Standards for SDI and e-Government'.

7.1 Standards for business process modelling

This section of the document provides an overview of standards, specifications and recommendations related to the business process modelling and management.

BPMN

As noted above, the Business Process Model and Notation (BPMN 2.0) is a specification from the Object Management Group (OMG). It has been also adopted as ISO 19510:2013. The specification provides a notation that is readily understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes. Thus, BPMN creates a standardised bridge between the business process design and process implementation.

This specification represents the amalgamation of best practices within the business modelling community to define the notation and semantics of Collaboration diagrams, Process diagrams, and Choreography diagrams. The intent of BPMN is to standardise a business process model and notation in the face of many different modelling notations and viewpoints. In doing so, BPMN provides a simple means of communicating process information to other business users, process implementers, customers and suppliers.

BPMN also provides the means to visualise the executable version of designed business processes (using BPEL).

Other notations and methods to design business processes are, among others: UML Activity Diagram, UML EDOC Business Processes, ebXML BPSS, Activity-Decision Flow (ADF) Diagram, RosettaNet and Event-Process Chains (EPCs).

WS-BPEL

The Web Services Business Process Execution Language specification (WS-BPEL 2.0 or "BPEL" in short) provides a language for formally describing business processes and business interaction protocols. It supports the description of business orchestration based on web services. WS-BPEL was designed to extend the Web Services interaction model to support business transactions.

BPEL is serialised in XML and aims to enable programming at a high or more generic level. This means that it supports programming of the high-level interactions of a process, where BPEL refers to this concept as an Abstract Process. A BPEL Abstract Process represents a set of publicly observable behaviours in a standardised fashion. An Abstract Process includes information such as when to wait for messages, when to send messages and when to compensate for failed transactions.

BPMN schemas can be translated into BPEL.

7.2 Standards for data modelling, metadata and data exchange

This section provides an overview of standards, specifications and recommendations related to data modelling, metadata and data exchange (encoding).

7.2.1 Data modelling and data models

UML (ISO 19501 and ISO 19505)

The Unified Modelling Language (UML) is a language for specifying, visualising, constructing, and documenting the artefacts of software systems, as well as for business modelling and other non-software systems. The UML represents a collection of the best engineering practices that have proven successful in the modelling of large and complex systems.

UML should be used in data modelling for object-orientated applications. Class diagrams, for instance, are the approach of choice and can also be used in other applications or by other tools. XML data structures can be directly generated from the corresponding specifications.

UML is used in the geospatial community to model and represent the 'real world'. In the context of INSPIRE, it is used to define the data specifications for the 34 INSPIRE themes in the form of application schemas for these themes.

UML has been adopted as ISO 19501:2005 (version 1) and ISO 19505:2012 part 1 and part 2 (version 2).

ISO 19100 series of standards

This series of standards is used to develop data specifications for the geospatial domain. It is a full suite of standards that are related to each other. They were used in the context of INSPIRE and other SDIs to define the content of those infrastructures. Semantics are encapsulated in the UML data model. The table below provides an overview of the most important standards.

Standard	Topic	Standard	Topic
ISO 19101	Reference model (2 parts)	ISO 19110	Feature cataloguing methodology
ISO/TS 19103	Conceptual schema language	ISO 19111	Spatial referencing by coordinates (2 parts)
ISO 19107	Spatial schema	ISO 19112	Spatial referencing by geographic identifiers
ISO 19108	Temporal schema	ISO 19117	Portrayal
ISO 19109	Rules for application schema	ISO 19131	Data product specification

This series of standards is also used by ISO/TC 211 to define specific thematic domains. Examples are the Land Administration Domain Model (ISO 19152) and the Land Cover Classification System (ISO 19144 part 1 and 2). Other supporting standards exist that help to solve particular issues, such as the definition of linear reference systems (ISO 19148) or specific standards related to quality (ISO 19157).

7.2.2 Metadata

Dublin Core

The Dublin Core Metadata Element Set is a vocabulary of fifteen properties for use in resource description: contributor, coverage, creator, date, description, format, identifier, language, publisher, relation, rights, source, subject, title and type. The name "Dublin" is due to its origin at a 1995 invitational workshop in Dublin, Ohio; "core" because its elements are broad and generic, usable for describing a wide range of resources such as web resources (video, images, web pages, etc.), as well as physical resources such as books or CDs, and objects like artworks.

The fifteen elements of Dublin Core described in this standard are part of a larger set of metadata vocabularies and technical specifications maintained by the Dublin Core Metadata Initiative (DCMI). The full set of vocabularies, DCMI Metadata Terms [DCMI-TERMS], also includes sets of resource classes (including the DCMI Type Vocabulary [DCMI-TYPE]), vocabulary encoding schemes, and syntax encoding schemes. The terms in DCMI vocabularies are intended to be used in combination with terms from other, compatible vocabularies in the context of application profiles and on the basis of the DCMI Abstract Model [DCAM].

Dublin Core is available as the following standards documents: IETF (Internet Engineering Task Force) RFC (Request for Comments) 5013 and ISO 15836-2009.

ISO 19115 and ISO 19139

Two specific standards for describing metadata for spatial data sets exist: i.e. ISO 19115 which consists of two parts, one for describing the schema required for describing geographic information and services by means of metadata, the second for describing metadata for gridded data; and ISO 19139 also consisting of two parts focussing on the XML schema for metadata. Over the past years, the metadata standards were updated and regrouped, although 19119 still exists and is still relevant. The metadata encoding became a new part (3) of the ISO 19115 standard. In addition, quality aspects of the data are described in ISO 19157 (data quality).

ADMS

As noted above, the Asset Description Metadata Schema (ADMS) is a vocabulary to describe interoperability assets making it possible for ICT developers to explore and search for interoperability assets. ADMS allows public administrations, businesses, standardisation bodies and academia to: describe semantic assets in a common way so that they can be seamlessly cross-queried and discovered by ICT developers from a single access point, such as JoinUp; search, identify, retrieve, compare semantic assets to be reused avoiding duplication and expensive design work through a single point of access; keep their own system for documenting and storing semantic assets; improve indexing and visibility of their own assets and link semantic assets to one another in cross-border and cross-sector settings.

ADMS can be used in the context of SDIs to describe, for example, tools to be used for implementing and maintaining the infrastructure, as partly demonstrated in platforms such as INSPIRE in Practice[66].

DCAT

As noted above, the Data Catalogue Vocabulary (DCAT) is a W3C recommendation designed in the Resource Description Framework (RDF) to facilitate interoperability between data catalogues published on the Web. This document defines the schema and provides examples for its use. By using DCAT to describe datasets in data catalogues, publishers increase discoverability and enable applications easily to consume metadata from multiple catalogues. It further enables decentralised publishing of catalogues and facilitates federated dataset search across portals.

DCAT does not make any assumptions about the format of the datasets described in a catalogue. Other, complementary vocabularies may be used together with DCAT to provide more detailed format-specific information. For example, properties from the VoID vocabulary [void] can be used to express various statistics about a DCAT-described dataset if that dataset is in RDF format. DCAT is applicable in many contexts including RDF accessible via SPARQL endpoints, embedded in HTML pages as RDFa, or serialised as, for example, RDF/XML or Turtle.

DCAT 2 has been developed and includes many new features, including the support for describing web services.

DCAT-AP

The DCAT application profile for data portals in Europe (DCAT-AP) is a specification based on DCAT for describing public sector datasets in Europe. Its basic use case is to enable cross-data portal search for data sets and make public sector data better searchable across borders and sectors. This can be achieved by the exchange of descriptions of datasets among data portals.

DCAT-AP makes it possible to: describe dataset collections in catalogues using a standardised description, while keeping their own system for documenting and storing them; aggregate such descriptions into a single point of access and easily find datasets from this single point of access.

GeoDCAT-AP

GeoDCAT-AP is an extension of DCAT-AP for describing geospatial datasets, dataset series and services. It provides an RDF syntax binding for the union of metadata elements defined in the core profile of ISO 19115:2003 and those defined in the framework of the INSPIRE Directive. This means that metadata elements that are very specific for the geospatial world, such as geographical extent, are also covered by the DCAT-AP standard which is used within the e-Government world. It facilitates searches for spatial datasets, data series, and services on general data portals, thereby making geospatial information also better-searchable across borders and sectors.

The GeoDCAT-AP specification does not replace the INSPIRE Metadata Regulation nor the INSPIRE Metadata technical guidelines based on ISO 19115 and ISO19119. Its purpose is to give owners of geospatial metadata

66 https://inspire-reference.jrc.ec.europa.eu/

the possibility to achieve more by providing an additional RDF syntax binding. Conversion rules to RDF syntax would allow Member States to maintain their collections of INSPIRE-relevant datasets following the INSPIRE Metadata technical guidelines based on ISO 19115 and ISO 19119, while at the same time publishing these collections on DCAT-AP-conformant data portals. A lossless conversion to RDF syntax allows additional metadata elements to be displayed on general-purpose data portals, provided that such data portals are capable of displaying additional metadata elements. Additionally, data portals may be capable of providing machine-to-machine interfaces where additional metadata could be provided.

XML Metadata Interchange (XMI)

XML Metadata Interchange (XMI) is a standard of the Object Management Group (OMG) which should be used in XML for the notation and interchange of Meta Object Facility (MOF)-based models (example: UML). This format is open and manufacturer-independent. UML 2.0 can be transformed to XMI 2.0 and XMI 2.1. XMI v2.0.1 was standardised as ISO/IEC 19503:2005.

7.2.3 Data exchange

XML

The Extensible Markup Language (XML) is a markup language defining a set of rules for encoding documents in a format which is both human-readable and machine-readable. It is defined as a free and open standard by W3C (XML 1.0) and for subsequent versions. The design goals of XML emphasise simplicity, generality and usability across the Internet. It is a textual data format with strong support via Unicode for different human languages. XML was originally designed to meet the challenges of large-scale electronic publishing. However, XML is playing an increasing role in the exchange of a wide variety of data on the Web by representing data structures such as those used in web services. Several schema systems exist to aid in the definition of XML-based languages, while many APIs have been developed to aid the processing of XML data.

XML Schema Definition (XSD) are XML based schemas used for the structured description of data. XML Metadata Interchange (XMI) is used to enable the easy interchange of metadata between application development lifecycle tools, including UML modelling tools and metadata repositories/frameworks based on the Meta Object Facility (MOF).

GML

Geographic Markup Language (GML) is a markup language used to exchange geographical information in vector format which considers spatial and non-spatial properties. GML does not contain any information concerning presentation on the screen or in a map and is used in the context of INSPIRE to encode and exchange spatial data sets.

GML has been adopted by ISO/TC 211 as international standard ISO 19136 and the specification has been adopted by the OGC. The general standard for encoding of geographical information is ISO 19118. While the latter defines the requirements for defining general encoding rules to be applied for encoding geospatial data, ISO 19136 is a specific implementation based on GML.

7.3 Standards for secure access

This section of the document provides an overview of standards, specifications and recommendations related to secure access to data and services including secure communication, authentication and authorisation.

7.3.1 Standards for securing communication

This section of the document provides an overview of standards, specifications and recommendations related the establishment of secure communication.

Standards associated with the Network Layer

IPSec

IPSec defines a protocol that secures Internet Protocol (IP) based communication between network endpoints on ISO/OSI layer 3 (network layer). It thereby creates secure tunnels through untrusted/unsecure networks ensuring confidential and authenticated communication. Sites connected by these tunnels form Virtual Private Networks (VPNs).

The following protocols are used in IPsec:

- ESP (Encapsulating Security Payload) is the encrypted information that is transported;
- AH (Authentication Header) provides authentication for data packets; and
- IKE (Internet Key Exchange) negotiates connection parameters.

The strength of IPSec is that applications can use the secure communication established (provided) by IPSec without any knowledge. Even though this is a strength, it should be stressed that IPSec does not establish an end-to-end secure communication, as it is provided by message layer security. This is important to understand when building a network topology that consists of multiple segments, each using their own IPSec configuration.

TLS / (SSL)

The Transport Layer Security/Secure Sockets Layer TLS/SSL protocol enables applications to communicate in a point-to-point fashion by establishing a secure communication channel that supports the integrity and confidentiality of the exchanged information. It requires that the server authenticates itself. Also, TLS/SSL provides optional mutual (client) authentication, which is almost never used. Based on a challenge request/response handshake that involves asymmetric encryption, the client and server establish (agree on) a shared secret (symmetric key) to encrypt all further communication that is associated to the current session.

Because TLS/SSL secures the entire information that is exchanged between communication partners, it cannot be used if individual parts of one message are, or the entire message is, confidential for receivers different from the client and the server. Also, transparent proxy connections are not possible.

In addition, the use of TLS/SSL is not sufficient if message repudiation is important, as the encryption is based on a shared secret. Here, message layer protection must be established to enable secure and trusted audit.

Standards associated with the Binding Layer

HTTP(S)

HyperText Transfer Protocol Secure HTTPS is defined as HTTP over TLS in the IETF RFC 2818. It defines how HTTP leverages TLS to establish a secure communication over the Internet using the https:// URI scheme**Error! Hyperlink reference not valid.** URI scheme. Simply speaking it is the result of an HTTPS connection communication of encrypted messages using the standard port 443.

Standards associated with Message Security

WS-Security

The prime goal of this OASIS specification is to enable secure exchange of XML messages using the SOAP protocol between communication end-points. It provides support implementing message integrity and confidentiality as well as client (user) authentication. This can be obtained by applying XML Digital Signature and XML Encryption to an XML message in a specific fashion. This standard describes the processing rules in order to create message integrity or confidentiality. It also describes the structure of SOAP messages and the structure or relevant metadata so that they can be processed (by web services) in an interoperable way.

This standard also supports different security tokens to obtain client authentication. It defines processing rules of how to attach security tokens to messages. These security tokens are currently supported:

- "Username" token provides support to share knowledge about the identity of a user. "Password" expresses the password associated with this token. In addition, "Nonce" and "Created" are supported to enable strong digested passwords.
- "X.509" token supports exchange and use of X.509 certificates for the matter of authentication, digital signatures and encryption.
- "SAML" include SAML assertions as a token.

- “Kerberos” token allows the use of Kerberos tickets.
- “REL” token can be used to attach license information.

Standards associated with Message Content Security

This section of the document provides an overview of standards, specifications and recommendations for establishing message content security.

XML Digital Signature

This W3C Recommendation specifies the processing rules on how to apply digital signatures to any type of information; in particular XML structures information, and how to represent the result, as well as the relevant metadata, in XML. It supports different kinds of digital signatures:

- “Enveloped” signatures are processed over the content that includes the digital signature element itself.
- “Enveloping” signatures are processed over content that is part of the signature element.
- “Detached” signatures are processed over content that is external to the signature element.

XML Encryption

This W3C Recommendation specifies the processing rules on how to encrypt information and represent the result, as well as relevant metadata, in XML. It also defines processing rules for the associated decryption. The following types of encryption are supported:

- “Element Encryption” supports encryption of the embracing element and its name.
- “Element Content Encryption” supports encryption of the value of an XML element which leaves the embracing element name in clear text.
- “Any Data Encryption” supports encryption of entire documents.
- “Super-Encryption” supports encryption of already encrypted data.

XKMS

The XML Key Management Specification (XKMS) is a W3C Note consisting of two sections specifying a XML Key Information Service (X-KISS) and a XML Key Registration Service (X-KRSS). It also involves the associated protocols for the distribution and registration of public keys that can be used in conjunction with the W3C Recommendations XML Digital Signature and XML Encryption.

- The Key Information Service Specification describes the protocols that allow an application delegating the processing of XML Digital Signatures (or parts of them) to a trusted service. The application hereby gains simplicity and performance issues concentrate on the trusted service.
- The Key Registration Service Specification describes the protocol to register (and revoke) public keys with a trusted service. The associated private key can be generated by the service or the client. This requires, in the first case, assertions by the client toward the proof of possession and, in the latter case, protocol mechanisms for securely sending the private key to the client. In order to allow a meaningful use of public keys and support for cryptographic verification, the client can request that the service registers particular information with a public key.

7.3.2 Standards for authentication

This section of the document provides an overview of standards, specifications and recommendations related to authentication and identity management.

X.509

An X.509 certificate is an information bundle where an identity is bound to a public key. The format of the identity can be an X.500 name, an email address or a DNS entry. The information bundle is digitally signed by the Certificate Authority (CA) which guarantees tamper resistance and authenticity. Today, version 3 of X.509 (x.509v3) is being used and allows the use of extension attributes that can be defined as necessary.

X.509 certificates are used to establish HTTPS communications, typically between a web browser and a web server. They are also used for signing emails, electronic documents such as PDF files or XML formatted messages that are sent by web services.

Because X.509 certificates are based on asymmetric encryption, a private key is associated to the public key. In order to create confidential documents and emails, an X.509 certificate can also been used.

PKI

Public Key Infrastructure (PKI), as described in the International Telegraph Union-Telecommunications (ITU-T) standard, provides the means by which public keys can be bound to identities in such a way that identification is possible without prior authentication. It also describes management procedures that guarantee that identities are unique throughout the Internet. This can be ensured creating a unique root certificate for each CA and each CA ensures that all maintained identities are unique throughout the CA.

So in a PKI, proof of identity is realised by use of X.509 certificates that are released by CAs. It is, therefore, essential that a trust relationship with the CA (from which the X.509 certificate is released) is established. This can be set up by accepting (or installing) the X.509 (root) certificate of the CA. With all standard web browsers, root certificates of all common CAs are pre-installed so that the user does not have to do that.

Apart from the management of identities through a certain number of trusted CAs, PKI also describes the means of revocation for X.509 certificates. Each CA maintains a so-called Certificate Revocation List (CRL) that contains the (permanently) revoked certificates. Even each certificate has a pre-defined lifecycle that is set at creation. It might be necessary that the certificate – so the assurance of the CA that a certain identity is bound to the certificate – expires prior to the pre-defined lifecycle. Reasons for revocation are given in the IETF RFC 3280. One reason could be that the private key that is associated with the identity has been tampered. Another reason could be that a certificate was released for a fraud identity.

Kerberos

Kerberos is a Computer Network Authentication Protocol developed by the Massachusetts Institute of Technology (MIT) that enables the provision of identities between communication partners to each other using a non-secure network. Therefore, Kerberos provides mutual authentication so that the user and the server can verify each other's identity. The protocol protects against eavesdropping (wiretapping) and replay attacks. Today, Kerberos is mainly used for authentication in Microsoft Windows Systems.

Technically, authentication is based on so called Kerberos Tickets. After a successful login at the Authentication Server (AS) using a long-term shared secret such as a username / password, the client receives a ticket from the AS. This AS-ticket can then be used to obtain shorter lifecycle tickets to be used with other servers.

LDAP

The Lightweight Directory Access Protocol (LDAP) is a protocol for querying and modifying entries of a Directory Service (DS). A DS is a computer programme that stores information (typically structured using X.500) about users and computers in a network. Each entry has a unique identifier, called the distinguished name (DN). Each entry can have additional attributes that have a name and a value that – as a whole – define the characteristics of the entry. The stored information is used by administrators to assign roles or access permissions to resources. In an Attribute Based Access Control (ABAC) System, the attributes and their values can be used to derive the authorisation decision. In such systems, it is vital to keep the X.500 structure backward compatible.

The LDAP can be used by other authentication protocols to query/exchange identity information.

XCBF

The XML Common Biometric Format (XCBF) is an OASIS standard that defines cryptographic messages, based on a common set of XML encodings for the Common Biometric Exchange File Format (CBEFF) that allow the secure collection, distribution and processing of biometric information for the purpose of authentication. In particular, it allows the verification of identity based on human characteristics such as DNA, fingerprints, iris scans and hand geometry.

SAML

The Security Assertion Markup Language (SAML) is an OASIS standard that specifies the structure, exchange and processing of assertions about the identity of a subject. An assertion is a structured package of information using the XML notation that is prepared and issued by a so called asserting party and consumed by a so called relying party. Constraints are specified by this standard that support the restrictions to be expressed by the asserting party to guarantee the appropriate consumption of assertions by the relying party. Also, assertions can be digitally signed to ensure integrity and authenticity. Encryption can be applied to make assertions or parts of it confidential and extension points are defined that allow the extension of assertion to meet project-specific needs. Three types of assertion are specified by the standard supporting different use cases at the relying party:

- "Authentication Assertion" provides information about the asserted subject toward the means by which a subject was authenticated, by whom and at what time.
- "Attribute Assertion" provides information about the characteristics of the asserted subject.
- "Authorisation Assertion" states that access to a particular resource is to be permitted/denied for the asserted subject.

With regard to exchange (request and response) assertions between the asserting and relying party, this standard specifies the following protocols (relevant excerpt) and the appropriate sequence of messages:

- "Assertion Query and Request Protocol" defines the processing rules of how existing assertions can be queried and the structure of the messages.
- "Authentication Request Protocol" enables the relying party to request assertion statements about the means by which a subject was authenticated.
- "Artefact Resolution Protocol" defines how SAML artefact references can be exchanged instead of the assertions itself.
- "Name Identifier Management Protocol" defines how an asserting party can change the name of an identifier that was previously established and is been used by relying parties.
- "Single Logout Protocol" defines a sequence of message exchange with the goal to terminate all existing sessions of the subject with other relying parties close to real time. However, there is no confirmation message because the logout with all relying parties cannot be guaranteed.
- "Name Identifier Mapping Protocol" defines an exchange of identifier names that can be used to establish identity federations.

An extension to the SAML standard defines the following bindings (relevant excerpts) that define an association of SAML protocol messages to the underlying communication/message protocols for a particular architecture:

- "SAML SOAP Binding" defines how SAML assertions are to be exchanged using SOAP messages and how SOAP header elements are to be used to do so.
- "Reverse SOAP (PAOS) Binding" describes a mechanism where the client is able to act as a SOAP responder or intermediary relevant for implementing the "Enhanced Client or Proxy (ECP) Profile".
- "HTTP Redirect Binding" enables the exchange of SAML messages as URL parameters. In order to ensure the length limit of a URL is not exceeded, message encryption is used. This binding is relevant, where HTTP user agents of restricted capabilities are involved in the message exchange.
- "HTTP POST Binding" defines how SAML messages can be sent inside a HTML form using base64 encoding.
- "HTTP Artefact Binding" defines how SAML request and response messages are exchanged using a reference – an artefact. This binding is essential for implementing the "Artefact Resolution Profile".

An extension to the SAML standard defines the following profiles (relevant excerpts):

- "Web Browser SSO Profile" defines how a Single-Sign-On can be established using a (regular) web browser as the client.

- "Single Logout Profile" defines the sequence of messages relevant to ensure that a user is logged out at all participating services.
- "Enhanced Client or Proxy (ECP) Profile" defines the exchange of request/response messages for a client that knows which asserting party to contact and knowing that it supports PAOS Binding.
- "Identity Provider Discovery Profile" defines mechanisms by which a relying party can discover which asserting parties a principal uses for the "Web Browser SSO profile".
- "Name Identifier Management Profile" defines mechanisms that can be used by the asserting/relying party to associate a different name to a principal.
- "Artefact Resolution Profile" defines a mechanism where client or client interface restrictions exist that prevents the direct exchange of SAML assertions. The SAML artefact is a unique (one-time) reference in the Internet, issued by the asserting party that points to a particular assertion stored at the asserting party that can be requested by the relying party.
- "Assertion Query/Request Profile" defines the basic mechanisms to query/request assertions using synchronous communication.
- "SAML Attribute Profiles" defines a unique naming for SAML attributes of "build-in" types such as X.500/LDAP, UUID, DCE PAC and XACML.

7.3.3 Standards for Authorisation (Attribute Based Access Control)

This section of the document provides an overview of standards, specifications and recommendations related to ABAC.

XACML

The eXtensible Access Control Markup Language (XACML), as specified in the OASIS standard, describes a multi-purpose Policy Language that allows access rights to be declared in XML. It further defines the process of interpreting Policies in order to derive an authorisation decision. In addition, it describes structures of request/response messages in XML that allows an authorisation decision to be requested from a Policy Decision Point (PDP), as it is useful in a Service Oriented Architecture (SOA).

Different profiles to XACML exist that define specific use of XACML. The following is an excerpt of important profiles:

- "RBAC Profile" defines how to declare XACML based access rights based on the Role Based Access Control (RBAC) Model. This profile supports RBAC0 (core RBAC) and RBAC1 (hierarchical RBAC). There is no support for RBAC2 (constraint RBAC).
- "SAML Profile" defines extensions to SAML so that XACML specific information can be securely exchanged. The following different extensions are defined:
    - "AttributeQuery" can be used for requesting one or more attributes from an Attribute Authority.
    - "AttributeStatement" defines a standard SAML statement that contains one or more attributes. This statement may be used in a SAML Response from an Attribute Authority, or it may be used in a SAML Assertion as a format for storing attributes in an Attribute Repository.
    - "XACMLPolicyQuery" can be used for requesting one or more policies from a Policy Administration Point (PAP).
    - "XACMLPolicyStatement" defines a SAML statement extension that can be used in a SAML response from a PAP.
    - "XACMLAuthzDecisionQuery" defines a SAML request extension that can be used by a Policy Enforcement Point (PEP) to request an authorisation decision from an XACML PDP. This is an alternative to the XACMLAuthorizationDecisionRequest defined in XACML.

    - "XACMLAuthzDecisionStatement" defines a SAML statement extension that can be used in a SAML response from an XACML PDP. This is an alternative to the XACMLAuthorizationDecisionResponse defined in XACML.
- "DSIG Profile" defines a recommendation to exchange authorisation decision requests and responses based on the SAML Profile for XACML that supports digital signatures to be applied for the purpose of authentication and establishing message integrity. This is a relevant profile as XACML itself does not support the application of digital signatures to the XACML native authorisation decision request and response messages.

GeoXACML

The Geospatial eXtensible Access Control Markup Language (GeoXACML) is a standard from the Open Geospatial Consortium (OGC) that defines a geo-specific extension to XACML v2.0. It extends the XACML Policy Language by the new data type "Geometry" and several geo-specific functions that allow the declaration and enforcement of access rights to be associated to geometric characteristics of a resource. The two extensions define particular XML encodings of a XACML AttributeValue element of type Geometry, based on the Geography Markup Language (GML). In particular, GeoXACML extension A provides support for GML2 and extension B provides support for GML3 formatted geometries.

7.4 Standards for licensing and e-business

This section of the document provides an overview of standards and recommendations related to Licensing/Digital Rights Management and e-Business.

7.4.1 Standards for licensing

XrML

The eXtensible Rights Markup Language (XrML) is a proprietary XML dialect to express rights over digital content which is used by Microsoft. It is not an international standard, but a *de facto* standard owned by ContentGuard (founded by Microsoft and Xerox) which holds related US patents. XrML version 1.0 is the successor of DPRL (Digital Property Rights Language) developed at Xerox PARC that defines computer work specific rights such as "copy" and "backup". Version 2.0 developed by ContentGuard was developed to be medium independent. Version 2.1 of XrML was standardised by ISO as Part 5 of the MPEG-21 standards suite (see next topic).

REL (Mpeg REL)

The Rights Expressions Language as specified in ISO/IEC 21000-5 defines an XML dialect to express usage rights through tamper-resistant enforceable licences for moving pictures (MPEG) files. In order to protect the owners' assets, a Digital Rights Management System is required of which REL is one key component.

ODRL

The Open Digital Rights Language (ODRL) Version 1.1 is a W3C Note that specifies an Expression Language and the representation in XML. It further defines the semantics of core expressions.

The core entities of the ODRL Language are Assets, Rights and Parties. An Asset represents the content that is to be protected either in physical or digital form. Rights include Permissions that are the actual usage that are allowed on the asset. The Parties represent the end user (consumer) and the Rights' holders that typically have been involved in the creation of the content, or who own it.

The standard defines, in the ODRL Data Dictionary Semantics section, a set of core rights and their semantics for Permissions, Constraints, Requirements, Rights Holders and Context. This standard also provides extension points for the definition of project specific data dictionary elements. One example given in the standard is associated to the mobile community, where rights such as "ring" or "send" are relevant.

7.4.2 Standards for e-business

This section of the document provides an overview of standards related to electronic business.

ISO/TS 15000

This multi-part international ISO standard defines the electronic business eXtensible Markup Language (ebXML) that provides support for an interoperable exchange of messages to facilitate global trade. In order to achieve the linking of business processes, each part of the standard defines certain (technical and non-technical) aspects such as Information Transfer, Meaning and Process. The main concern with Information Transfer is the safe and reliable exchange of information (messages) over the (unsecure) Internet. The Meaning aspect establishes a common (identical) understanding of the exchanged information about the order and/or deliverable. The Process aspect is related to the standardisation of the sequence of actions concerning messages to be sent and orders to be fulfilled. In addition, ebXML defines the structure of an ebXML registry, where process, messages and data definitions can be stored, as well as the mechanisms that guarantee inter-registry communication for the purpose of synchronisation.

Part 1 defines the collaboration-protocol profile (ebCPP) that can be used for business transactions between business communication partners. Part 1 also defines the agreement specification (CPA) that can be used as a message exchange agreement between the business partners. The CPA defines the minimum agreement towards message, communication security constraints, that are created by the intersection of the business partners' CPPs. The CPA also contains a binding to a Process Specification document that defines the interactions between the business partners, specific to the actual business collaboration.

Part 2 defines a communications-protocol (ebMS) neutral method for exchanging electronic business messages that ensures the reliable and secure delivery of business messages. In particular, the ebXML message structure is defined, as well as the behaviour of the message handling services that are used to send and receive ebXML messages. In order to achieve this, the ebXML SOAP Envelope extension is defined and the Reliable Messaging protocol is leveraged to ensure the once-and-only-once message delivery semantics.

Part 3 defines the registry information model (ebRIM) in which the term "repository item" is used to identify the actual information object that is stored in the registry (e.g. XML document) and the "RegistryEntry" which is used to refer to metadata about a repository item. The information, stored in an ebXML registry can be used to facilitate ebXML-based B2B partnerships or transactions. The Registry Information Model defines what types of objects are stored in the registry and how the stored objects are organised in the registry. It acts as a blueprint for implementers to decide which types to include in the registry and which attributes and methods the actual objects might need. The actual Registry Information Model is provided as UML diagrams, in which different classes and their associations are introduced: RegistryObject, Slot, Association, ExternalIdentifer, ExternalLink, ClassificationScheme, ClassificationNode, Classification, RegistryPackage, AuditableEvent, User, PostAddress, EmailAddress, Organization, Service, ServiceBinding and SpecificationLink.

Part 4 defines how to build ebXML registry services (ebRS) to provide access to the information stored in an ebXML registry. It, therefore, defines interfaces for the registry service, the interaction protocol and message structures.

7.5 Standards for web services

This section of the document provides an overview of standards, recommendations and other literature related to securing Web Services.

7.5.1 General web service standards

SOAP

The Simple Object Access Protocol (SOAP) provides the foundation of communication for web services. SOAP defines a particular XML structure that separates the information of a message into a "Header" and a "Body" part. The "Body" part of the message contains the actual information that is to be transported and the "Header" element can keep optional (security related) metadata as is relevant to protect the "Body" information as a whole or partially.

SOAP supports multiple bindings, where the HTTP (and HTTPS) binding is the most common one. It enables the communication between sites using the "standard" WWW port to pass through a firewall.

WS-Security defines mechanisms and XML structures for protecting SOAP messages in an interoperable way (so that they can be understood by the receiver) allowing integrity and confidentiality using XML Digital Signatures and XML Encryption.

For some use cases, the input and/or output of a web service might be in binary format instead of XML. For these cases, a base64 encoding of the binary data can be transported in the SOAP Body. However, although this is possible, the base64 encoding increases the size of the information and the XML parsing, digital signatures and encryption, which leads to a decrease in performance. In order to exchange binary data via SOAP, SOAP with attachments can be used.

REST

Representational State Transfer (REST) is a software architectural style that defines a set of constraints to be used for creating Web services. Web services that conform to the REST architectural style, called RESTful Web services, provide interoperability between computer systems on the Internet. RESTful Web services allow the requesting systems to access and manipulate textual representations of Web resources by using a uniform and predefined set of stateless operations. Other kinds of Web services, such as SOAP Web services, expose their own arbitrary sets of operations (W3C, 2016).

WSDL

In order to bind to a web service, its network end points (operations and binding) and the (SOAP) structure of input and output message can be described using the Web Services Description Language (WSDL). More precisely, WSDL is a W3C note that defines a model and the XML notation to describe web services to support ease of use by the following elements:

- The “types” element describes the messages that can be received and sent by the web service
- The “interface” element contains information about the functionality of the web service
- The “binding” element has the information of how to access the web service
- The “service” element provides the actual network endpoint where the web service can be accessed

WSDL 2.0 supports a full HTTP binding including GET / POST (/ DELETE / PUT / etc.) and SOAP.

7.5.2 Web service standards for geographic information

CSW

CSW (Catalogue Service for the Web) is an OGC standard that specifies the interfaces, bindings, and a framework for defining application profiles required to publish and access digital catalogues of metadata for geospatial data, services, and related resource information. Metadata act as generalised properties that can be queried and returned through catalogue services for resource evaluation and, in many cases, invocation or retrieval of the referenced resource. Catalogue services support the use of one of several identified query languages to find and return results using well-known content models (metadata schemas) and encodings.

WMS and WMTS

The WMS (Web Map Service) Interface Standard from OGC provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc.) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent, so that layers from multiple servers can be combined or not. WMTS (Web Map Tile Service) is a specific implementation of WMS, to serve and consume rendered map tiles. It can be combined with other OGC standards and also integrated with the emerging RESTful[67] applications and "mash-ups". WMS has been adopted by ISO/TC 211 as ISO 19128.

WFS

WFS (Web Feature Service) is another OGC Web Service standard. WFS provide transactions on and access to geographic features in a manner independent of the underlying data store. It specifies discovery operations, query operations, locking operations, transaction operations and operations to manage stored parameterised

[67] RESTful refers to the application of an architectural style for the World Wide Web: it refers to the elaboration of ‘simple’ components e.g. in the form of services.

query expressions. Discovery operations allow the service to be interrogated to determine its capabilities and to retrieve the application schema that defines the feature types that the service offers. Query operations allow features or values of feature properties to be retrieved from the underlying data store based upon constraints, defined by the client, on feature properties. Locking operations allow exclusive access to features for the purpose of modifying or deleting features. Transaction operations allow features to be created, changed, replaced or deleted from the underlying data store.

Stored query operations allow clients to create, drop, list and described parameterised query expressions that are stored by the server and can be repeatedly invoked using different parameter values.

WFS has been adopted by ISO/TC 211 as ISO 19142.

Other service interfaces have been defined by OGC such as **WCS** (Web Coverage Service) and **WPS** (Web Processing Service). The WCS is meant to provide access to geospatial data which are in the coverage (i.e. they are gridded) format. A user can select a specific spatio-temporal location (a part of a coverage for a certain period) of a coverage. WPS provides rules for standardising the inputs and outputs (requests and responses) for geospatial processing services, such as polygon overlay, buffering or other specific geospatial processes. The standard also defines how a client can request the execution of a geospatial process, and how the output from the process is handled.

7.5.3 API Standardisation

OpenAPI Specification (OAS)

OAS defines a standard, programming language-agnostic interface description for REST APIs, which allows both humans and computers to discover and understand the capabilities of a service without requiring access to source code, additional documentation or the inspection of network traffic. When properly defined via OpenAPI, a consumer can understand and interact with the remote service with a minimal amount of implementation logic. Similar to what interface descriptions have done for lower-level programming, the OpenAPI Specification removes guesswork in calling a service (OpenAPI Initiative). OAS is used for the development of OGC APIs.

OGC API Features

OGC API Features provides API building blocks to create, modify and query features on the Web. OGC API Features is comprised of multiple parts, each of them is a separate standard. This part, the "Core," specifies the core capabilities and is restricted to fetching features, where geometries are represented in the coordinate reference system WGS 84 with axis order longitude/latitude.

OGC SensorThings API

The OGC SensorThings API provides an open, geospatial-enabled and unified way to interconnect the Internet of Things (IoT) devices, data and applications over the Web. At a high level, the OGC SensorThings API provides two main functionalities and each function is handled by a part. The two parts are the Sensing part and the Tasking part. The Sensing part provides a standard way to manage and retrieve observations and metadata from heterogeneous IoT sensor systems. The Tasking part is planned as a future wo rk activity and will be defined in a separate document as the Part II of the SensorThings API.

GeoAPI

The GeoAPI Implementation Standard defines, through the GeoAPI library, a Java language API including a set of types and methods which can be used for the manipulation of geographic information structured following the specifications adopted by ISO's TC211 and by the OGC. GeoAPI standardises the informatics contract between the client code which manipulates normalised data structures of geographic information based on the published API and the library code able both to instantiate and operate on these data structures, according to the rules required by the published API and by the ISO and OGC standards.

7.5.4 Web service standards for security

WS-Addressing

Web Services Addressing is a W3C Recommendation that supersedes the WS-Referral and WS-Routing initiatives by Microsoft. It specifies a transport neutral mechanism to communicate addressing information for messages and service endpoint references. Using SOAP and HTTP(/HTTPS) the sender relies on the Transmission Control Protocol/Internet Protocol (TCP/IP)[68] to route the message to the right receiver. Once delivered, the receiver uses information from the SOAP-message to figure out what to do with the message. WS-Addressing allows this relationship to be disconnected by inserting WS-Addressing metadata information (structured in XML) into the SOAP Header. From a security point of view, this enables communication partners to securely exchange synchronous but more importantly asynchronous (unsolicited) messages. In order to ensure trusted processing, XML Digital Signature can be applied to make WS-Addressing metadata tamper resistant and authentic.

"Web Services Policy Attachment for Endpoint Reference (WS-PAEPR)" describes how to use WS-Policy Information in the Endpoint Reference provided by WS-Addressing. This enables service security requirements to be expressed that ought to be met in order to access (execute) the referenced service.

WS-Policy

Web Services Policy is a W3C Recommendation that allows policies of a web service to be described and advertised in XML. A policy can express requirements towards Quality of Service characteristics, privacy considerations and security constraints, amongst others.

From the standpoint of security, WS-Policy describes the capabilities and constraints of the security policies on intermediary services and end point services such as required security tokens and supported encryption algorithms. WS-Policy also defines how to associate policies with web services. In addition, WS-Policy defines operators to combine and intersect policies.

WS-Policy Attachment

Web-Services Policy Attachment is a W3C Recommendation that is based on WS-Policy. It specifies how to derive the effective policy for subjects from "scattered" policies by merging all relevant parts. This is important as constraints can be expressed at different levels (web service, operation, message, communication channel, environment, authorisation, cryptographic algorithms, tokens, etc.) that must be considered at the moment when authorisation is enforced.

In addition, this recommendation specifies two general-purpose mechanisms for associating policies to different versions of WSDL and Universal Description, Discovery and Integration (UDDI), where the latter defines a registry service for publishing, searching and obtaining WSDL documents.

The specified model for attaching WS-Policies to WSDL includes how to partition a WSDL construct into "service", "endpoint", "operation" and "message" policy subjects and the semantics for attaching a policy to each policy subject. It further defines how to combine policies for a single policy subject that is attached to multiple WSDL components.

WS-SecurityPolicy

Web Services SecurityPolicy is an OASIS standard that defines a framework that enables the specification of web services security related constraints and requirements that can be used in conjunction with WS-Policy.

In order to support this, WS-SecurityPolicy defines initial sets of assertions that are used by the service to express to the client how messages can be secured. The intent is to be flexible on the one hand, in terms of tokens and cryptographic algorithms, but remain expressive, on the other, to ensure interoperability toward assertion matching between communication partners.

WS-SecurityPolicy supports the following types of assertions:

- "Protection assertions" define the parts of a message that are to be protected.
- "Conditional assertions" define preconditions of security, such as which tokens can be used for integrity or confidentiality or which cryptographic algorithms can be used.
- "Security binding assertions" define how Conditional assertions are to be used to protect message parts, as declared using Protection assertions.

[68] TCP/IP specifies how data should be packetised, addressed, transmitted, routed and received at the destination.

- “Supporting token assertions” define the types of tokens that can be used to secure individual operations of the service or messages.
- “Web Services Security and Trust assertions” define token referencing and additional trust options.

WS-Trust

Web Services Trust is an OASIS standard that defines extensions to WS-Security for managing (issuing, renewing, cancelling, validating) security tokens for the purpose of establishing brokered trust relations between web services of communication partners through the exchange of secured messages. For supporting Brokered Trust, this standard introduces the concept of a Security Token Service (STS). In order to use the STS in an interoperable way, XML message formats are defined for the messages to request and respond to security tokens, as well as negotiation and challenging mechanisms.

It is important to note that this specification does not define any security token types. It just specifies how to deal with them to establish trust between web services of not directly trusted communication partners.

WS-SecureConversation

Web Services Secure Conversation is an OASIS standard that defines the concept of a Security Context (Security Context Token), and how to establish and/or reference it in order to exchange a sequence of messages within a session instead of single messages, as supported by WS-Security. This standard defines three ways of establishing a security context:

- Security Context Token (SCT) created by a security token service;
- SCT created by one of the communication parties and propagated with a message; and
- SCT created by negotiation.

In addition, the standard defines mechanisms for amending, renewing and cancelling an established security context. Because the encryption of the messages exchanged within an established security context is based on shared secrets, this standard also defines how to derive keys, as well as the refreshing of keys, in order to prevent too much encrypted data to be provided for analysis.

This standard is designed to be used in conjunction with other WS-* standards, in particular WS-Security and WS-Trust.

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List of abbreviations and definitions

Abbreviations

ADMS	Asset Description Metadata Schema
AGIV	Agency for Geographic Information in Flanders
API	Application Programming Interface
ARE3NA	A Reusable INSPIRE Reference Platform (ISA)
BIN	Business and Organisation Number (NORA)
BPEL	Business Process and Execution Language (Web Service BPEL)
BPMN	Business Process Model and Notation
BSN	Unique ID for Citizens (NORA)
CCO	Contact Centre of the Government (NORA)
CIRB	Centre Informatique pour la Région Bruxelloise
CISQ	Consortium for IT Software Quality
CKAN	Comprehensive Kerbal Archive Network
CRAB	Central Reference Address Database
CSCC	Cloud Standards Customer Council
CSW	Catalogue Service for the Web
DCAT	Data Catalogue Vocabulary
DCAT-AP	DCAT Application Profile
DERI	Digital Enterprise Research Institute
DG CONNECT	Directorate General for Communications Networks, Content & Technology
DG DIGIT	Directorate General for Informatics
DG EUROSTAT	Directorate General for statistics, the statistical office of the EU
DGWIG	Defence Geospatial Information Working Group of the USA
DIGID	Digital Identity
DoaP	Description of a Project
DoD	Department of Defence of the USA
DYA	Dynamic Architecture
EFIR	European Federated Interoperability Repository

EIA	European Interoperability Architecture
EIC	European Interoperability Architecture Cartography
EIRA	European Interoperability Reference Architecture
EIF	European Interoperability Framework
EIS	European Interoperability Strategy
eNIK	Electronic ID-Card (NORA)
EULF	European Union Location Framework
FOAF	Friend of a Friend
G2B	Government to Business
G2C	Government to Citizen
G2G	Government to Government
GBA	Geological Survey Austria
GEAM	Gartner Enterprise Architecture Method
GERAM	Generalised Enterprise Reference Architecture and Methodology
GeoDCAT-AP	DCAT-AP implementation for geographic information
GIS	Geographic Information System
GMES	Global Monitoring Environment and Security
GML	Geographic Markup Language
HTML	Hyper Text Markup Language
HTTP	Hypertext Transfer Protocol
HTTPS	Secured HTTP
IAF	Integrated Architecture Framework
ICT	Information and Communication Technology
IDABC	Interoperable Delivery of European eGovernment Services to public Administrations, Businesses and Citizens
INSPIRE	Infrastructure for Spatial Information in Europe
ISA	Interoperable Solutions for Public Administrations
ISO	International Organisation for Standardization
JAXB	Java Architecture for XML Binding

JRC	Joint Research Centre
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
KOSIT	German Federal Ministry of the Interior
MIG	INSPIRE Maintenance and Implementation Group
MDA	Model Driven Architecture
MOG	Gemodelleerde Overstromingsgebieden – Modelled Flood Areas
NGA	National Geospatial-intelligence Agency
NOG	Natuurlijke Overstromingsgebieden – Natural Flood Areas
NORA	Nederlandse Overheid Referentie Architectuur – Dutch Government Reference Architecture
NUTS	Nomenclature of territorial units for statistics
OASIS	Organisation for the Advancement of Structured Information Standards
OCL	Object Constraint Language
ODIP	Open Data Interoperability Platform
OMG	Object Management Group
OGC	Open Geospatial Consortium
OSLO	Open Standards for Linking Governments
OWL	Web Ontology Language
OWS	OGC Web Services
PIP	Personal Internet Pages
POG	Potentiële Overstromingsgebieden – Potential Flood Areas
PSI	Public Sector Information
PwC	PricewaterhouseCoopers
RDF	Resource Description Framework
RM-ODP	Reference Model for Open Distributed Processing
ROG	Recente Overstromingsgebieden – Recently Flooded Areas
SAGA	Standards and Architectures for eGovernment Applications
SAM	Software Asset Management

SDI	Spatial Data Infrastructure
SDO	Standards Developing Organisations
SKOS	Simple Knowledge Organisation System
SLD	Styled Layer Descriptor
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SPDX	Software Package Data Exchange
STORK	Secure idenTity acrOss boRders linKed
TAFIM	Technical Architecture Framework for Information Management
TEN-T	Trans-European Network – Transport
TOGAF	The Open Group Architecture Framework
UML	Unified Modelling Language
URI	Uniform Resource Identifier
USGS	United States Geological Service
W3C	World Wide Web Consortium
WCS	Web Coverage Service
WFS	Web Feature Service
WFS-T	Transactional WFS
WMS	Web Map Service
WSFL	Web Services Flow Language
XHTML	Extensible Hypertext Markup Language
XML	Extensible Markup Language

Definitions

Business process	A process is defined as the way in which organisations create products, services and policies. It is a succession of interconnected activities that, starting from an identifiable input, result in a defined output in the form of a product or service (Dessers et al., 2010). Also used: e-Government process, work process, work flow
Code List	Complete set of data element values of a coded simple data element [ISO 9735-1:2002, 4.14].
Core Vocabulary	A Core Vocabulary is a simplified, reusable, and extensible data model that captures the fundamental characteristics of an entity in a context-neutral way (ISO, 2014).
Descriptions of Semantic Interoperability Assets	Descriptions of assets that can be contained in and made available from the semantic interoperability repositories (PWC EU Services, 2012).
Digital Government	Government designed and operated to take advantage of information in creating, optimising, and transforming, government services.
Domain Model	A domain model is a conceptual view of a system or an information exchange in a defined area that identifies the entities involved, and their relationships (W3C, 2004).
e-Government (electronic government)	Is the use of electronic information and communication technologies in order to involve citizens and businesses in the activities of government and the public administrations, as well as facilitating interaction between administrations (ISA, 2015).
e-Government Metadata	Descriptions of e-Government Primary Resources such as in metadata records or statements in databases that provide information about these e-Government resources and how they can be used (PWC EU Services, 2012).
e-Government Primary Resources	Primary data resources such as documents, services, software, datasets (PWC EU Services, 2012).
e-Government Service	Within the scope of e-Government, the term "service" is understood to be the execution or result of an activity by a public administration which serves the citizen, business or another public administration/agency.
(Geospatial) Web Service	A Web service is a software system designed to support interoperable machine-to-machine interaction over a network (W3C, 2004). INSPIRE network and spatial data services, OGC Web Services (OWS) (OGC, 2015).
Schema	A schema is a concrete view on a system or information exchange, describing the structure, content, and semantics of data (PWC EU Services, 2012).
(Semantic) Interoperability	Interoperability is the ability of information and communication technology (ICT) systems and the business processes they support to exchange data and to enable the sharing of information and knowledge. Semantic interoperability is about the meaning of data elements and the relationship between them. It includes developing a vocabulary to describe data exchanges, and ensures that data elements are understood in the same way by communicating parties (EIF v1.0, ISA, 2004; EIF v2.0, ISA 2011).

Semantic Interoperability Assets	Highly reusable metadata (e.g. XML schemata, generic data models) and reference data (e.g. code lists, taxonomies, dictionaries, vocabularies) which are used for e-Government system development (PWC EU Services, 2012).
Taxonomy	Scheme of categories and subcategories that can be used to sort and otherwise organise items of knowledge or information [ISO/DIS 25964-2]
Thesaurus	A controlled and structured vocabulary in which concepts are represented by terms, organised so that relationships between concepts are made explicit, and preferred terms are accompanied by lead-in entries for synonyms or quasi-synonyms [ISO 25964-1:2011].

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