Semantic Services

WWRF WG2 White Paper

WG2-WPxx

Version 0.90

Josef Noll[1], Matthias Wagner[2], Massimo Paolucci[2], Erik Lillevold[1], Anna V. Zhdanova[3], Mohammad M.R. Chowdhury[1]
external contributions: Kashif Iqbal[4], Dumitru Roman[5]

1 University Graduate Center, UniK, Kjeller, Norway
2 DoCoMo, EuroLab, Germany
3 Forschungszentrum Telekommunikation Wien, Austria
4 DERI, National University of Ireland, Galway, Ireland
5 DERI Innsbruck, Austria

Keywords: service, web, user, semantic, ontology, Semantic Web Services, mobile applications, language, environment

Table of Content

1. Introduction....3
2. Objective and Scope....4
  - 2.1 Objectives....4
  - 2.2 Scope....4
  - 2.3 Approach....6
  - 2.4 Semantic Service Scenarios....6
3. From Web Services towards Semantic Web Services....8
  - 3.1 Evolution to future service provisioning....8
  - 3.2 Semantic Web....10
    - 3.2.1 Ontologies....10
    - 3.2.2 Mobile Ontology: Ontology Adoption for Mobile Services....11
  - 3.3 Semantic Web Services....13
    - 3.3.1 Web Ontology Language for Services (OWL-S)....14
    - 3.3.2 Web Services Semantics (WSDL-S)....14
    - 3.3.3 Semantic Web Services Framework (SWSF)....15
    - 3.3.4 Web Service Modelling Ontology (WSMO)....16
    - 3.3.5 SAWSDL....16
    - 3.3.6 Comparison of approaches....16
4. Challenges....18
  - 4.1 Service Realisation and Expectations....18
    - 4.1.1 Semantic service architecture interfaces....18
    - 4.1.2 Mediation of ontologies....19
    - 4.1.3 Industry standards....20
    - 4.1.4 Other semantic web service implementations....20
    - 4.1.5 Semantic support for user centric services....21
  - 4.2 Mobile Semantic Services....21
    - 4.2.1 Personalisation and context aware services....22
    - 4.2.2 Conclusions for semantically supported mobile services....22
5. Business Considerations....23
6. Summary and Outlook....25
7. References....27

1. Introduction

The next generation (beyond 3G) of mobile services and applications must offer an increasing level of value and differentiation, they have to adapt to the user preferences, be aware of the user context, and adapt to the device and the radio environment. These services must also be developed easily, deployed quickly and, if necessary, altered efficiently.

Machine understandable descriptions of both user context, preferences and service capabilities are the key for an automated service adaptation. Semantic technologies support the machine readability of content, and became part of the service oriented architecture (SOA). This white paper focusses on the challenges of service delivery in a ubiquitous service environment, supporting the preferences and context of the user and his communication devices. Historically a service centric architecture was introduced to let services communicate with each other. WWRF's user- or I-centric approach is based on the transition of access delivery to service delivery [Kellerer2002]. Current rule-based algorithms become too complex when handling user context and preferences, thus asking for new mechanisms allowing dynamic adaptability of services.

The service centric world was introduced based on service level agreements (SLA) between trusted partners. In a more dynamic service provisioning world, as envisaged in a Semantic Web Services environment, privacy and security become key issues [Kagal2004]. Our approach is to take advantage of developments in both worlds, using the security and privacy mechanisms of the I-centric world and combine them with the semantic representation of data as known from the Semantic Web (Services) World [McIlraith2001].

The key challenge in a user-centric approach is the handling of user preferences, context, devices, and connectivity. Experiences from implementations in international projects showed that managing and updating preferences is a tedious work and that users often disagree with the selected services resulting from a rule-based decision engine. While the home is a rather controlled environment, with trusted and known constellations of devices, service delivery in the mobile/wireless world is more complex. Louis V Gerstner, Jr of IBM said: *Picture a day when a billion people will interact with a million eBusinesses via a trillion interconnected, intelligent devices*. Pervasive systems *does not just mean computers everywhere; it means computers, networks, applications, and services everywhere.* The report from the UK Technology Strategy Board [UK-Tech2006] pointed out that the high-added value comes from:

- **Always on** - availability of the right content at the right place and time.
- **User-centric** solutions - simple and practical person-oriented solutions.
- **Invisibility** - numerous, casually accessible, often invisible computing devices.
- **Intelligence** - removing the cognitive load through devices with embedded sensing and processing capabilities.
- **Increasing productivity** - market value propositions: saving time, saving money.
- **Life-enhancing** - penetration of technology into mainstream mass market applications.
- **Innovation** - using technology in ways that empower people to work, live, and play in radically new ways.
- **Omnipresent** - embedded into everyday devices and objects all around.

- **Ubiquity** - everyone and everything connected to an increasingly ubiquitous network structure.

To build these types of personalized services is a challenge to the system design as well as user description. This white paper will address some of the challenges.

2. Objective and Scope

2.1 Objectives

The objective of the WWRF WG2 is to create a technology independent blue print of next generation service platform architecture. The architecture is used as a basis for a discussion with the different players; this includes the understanding why market participants have come up with new architectures as well as a clear understanding about the underlying network architectures.

Semantic service provision is seen as a glue to connect the different platform parts in an economic way, and thus link service environment, user aspects, and user context together to form a dynamic service world.

Further steps in WWRF WG2 are to bring the WG2 results into a system architecture, identifying (high level) components, their distribution and their interworking (interfaces and protocols) based on intensive discussions among experts from operators, manufacturers, content providers, IT/software industry, and academia.

The task of this white paper on Semantic Services is to elaborate where semantic definitions can support the foreseen WG2 architecture for personalized and trusted services.

2.2 Scope

A next generation mobile service network has to establish its own value proposition between the stakeholders of next generation mobile service provisioning. It has to place its unique selling points into the overall service centric environment dealing with a number of different access systems. Mobile and wireless networks have the potential to act in a central role within this service environment and is therefore required to be capable to act as a service control environment. It is not the intention to copy all successful internet services but to support them in an efficient and trustworthy way.

The service platform architecture is interfacing to the services and applications at the upper layer of a communication system. The Service Platform Architecture covers service support components (such as Generic Service Elements), their relationship and their internal and external interfaces. It usually targets the upper system layers as depicted in Figure 1, however some functions or parts of them are residing in lower system layers, e.g., location or mobility. When considering ubiquitous communications environments such as sensor networks the layering is diminishing anyway.

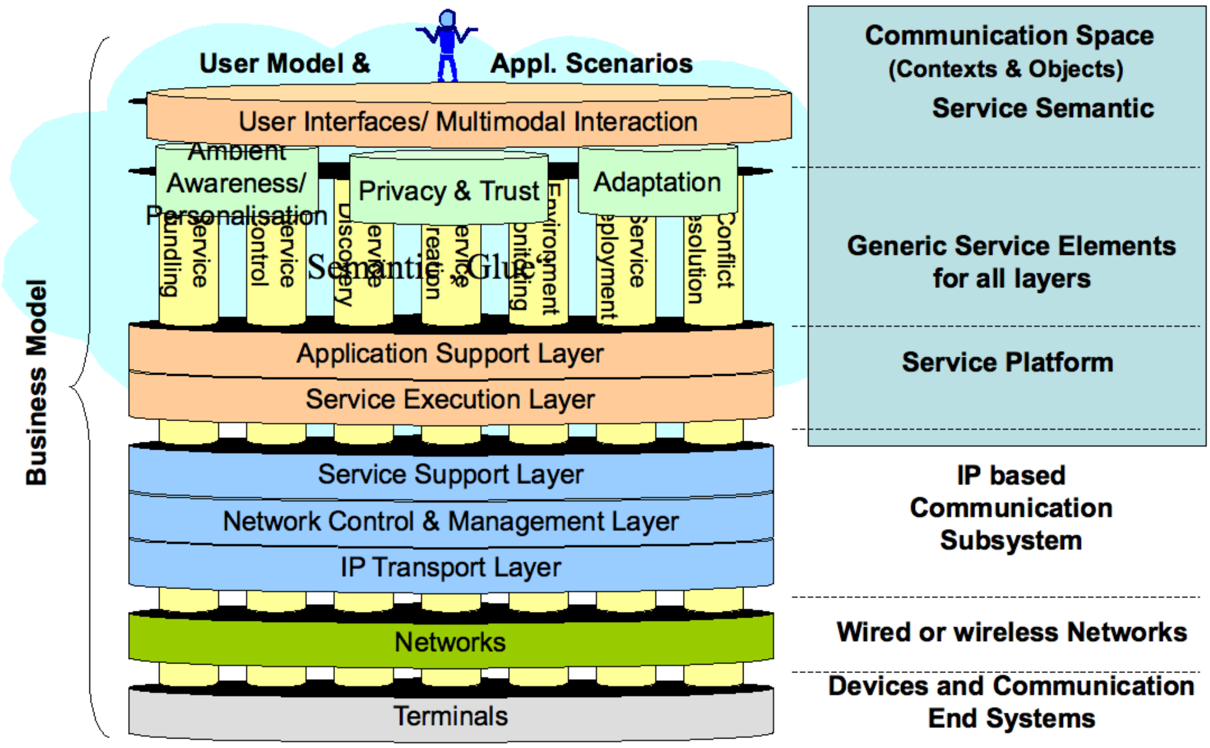


Figure 1: Target area of the WG2 architecture work shown in the reference model

Service Architecture for future mobile systems must be able to satisfy requirements from a broad range of services and different kinds of service usage. This can be reflected in the consideration and analysis of various future life scenarios. With this approach a scenario centred design process can be applied.

KLAUS, this section needs links to other white papers and your handwriting.

Although a number of scenarios are available, their impact on service architectures is rarely obvious. The reason might be that service architectures have not been in the focus of the scenario creator at all. Alternatively, the scenarios might be tailored to specific service architectures, i.e. those activities do not comply with the scenario centred design process. In cases where scenarios were in fact considered for the design process, these are often describing very specific aspects and the resulting service architectures are very much tailored to them.
To gain the desired demands from future life scenarios on service architectures it is required to evaluate a selection of scenarios to derive commonalities and their specific features. A first analysis resulted in a number of aspects which can be taken as initial input for the service architecture design: Future Services will be context-sensitive, adaptive and personalized. They will be available in different networks, with different bandwidth/QoS and for different devices or multi-modal UIs respectively. Service architectures need to support sophisticated charging and billing, security and privacy, identity management, DRM, and trust. The complete service life cycle is to be reflected: from service creation and composition to service discovery and delivery. Semantically described services can provide a cost-effective service environment (see chapter 5), supporting especially service testing and service update. In addition, semantic descriptions ease user preference descriptions and support community tagging.

2.3 Approach

Based on the current developments in semantic service delivery, WWRF WG2 proposes the following approach to address the above stated objectives and scope of future service architectures:

- Use semantics to describe the service environment, including
    1. User preferences, profiles and roles
    2. User context like location, communication capabilities and connectivity
    3. Interfaces to the service world
- Establish a semantic service architecture, supporting automated service incorporation and configuration of complex services
- Specify the transmission zone between the remote service world (Internet services) and the wireless (phone or proximity) service environment of the user.
- Identify unique selling points as Value Added Services (= high level features) provided by Mobile Service Platforms
- Verify the Value Added Services with service scenarios
- Identify a suitable architecture supporting those features and addressing the above stated scope
- Design of an architecture blueprint in terms of high level components and interfaces
- Identify platforms and software engineering methods for its realisation

WWRF WG2 sees a semantic user preference description as a potential way to establish a dynamic service offer to the end-user, adjusted to the needs and the context of the user.

2.4 Semantic Service Scenarios

In this section we will concentrate on just one scenario describing several aspects of semantic service provision. The scenario is taken from the EU FP6 project Adaptive Services Grid (ASG) and provides a service world for a mobile traveller [ASG D7.IV, 2006]. Similar scenarios are known from other projects describing the dynamics of a future service world.

The mobile traveller scenario belongs to the group of location based services (LBS). The scenario is targeted at mobile users with limited web access as well as at all (other) users with respect to the composition of a number of atomic services which together fulfil the demands of the end service user.

The typical chain of events is that an end service user is in a situation where he needs a specific service and uses e.g. the cell phone to access such service. The service itself is composed and presented by the ASG platform. To give examples, these services address situations, where the user needs location specific information on (this list is not exhaustive):

- Hotels
- Restaurants
- Restroom facilities
- Fuelling stations
- Service stations
- Garage / repair shops

- Pharmacy
- Dentist
- Medic / Hospital

This information can be enhanced through services, e.g. a route guidance to the destination.
An important aspect of the scenario is that it covers the complete service chain from service discovery to billing. In fact, billing is a crucial aspect since it has been shown over the last years that end service users are used to getting services for free from the Internet and, hence, are not (or hardly) willing to pay for such services. A common attempt to deal with that is to try to get money from advertising. Telenor Research has delivered a number of interesting aspects on this and on further aspects regarding the willingness to pay.
Another situation where an end service user is willing to pay is in emergency situation: Emergency services (not only sirens and flashing lights but also finding a pharmacy or even an available room) are of special interest since they form one of very few classes of services where the end service customer is willing to pay for the use. So, profitable business will be possible on the market of services with that service class.
In an abstraction of a location based service it does not matter whether a local attraction shall be booked or whether a taxi or hotel is needed in an unknown environment, or even if a traffic accident occurred and immediate help is needed. At this point it shall be pointed out that mobile users are a very important target group for this kind of services. Mobile users, who either travel on their own or by car. The car is the most appealing environment for mobile users, as all the services addressed here can easily be ported to public transportation or other means of private transportation. This is why the following part of this subsection focusses on the use of ASG mechanisms in the vehicle.

The mobile user in the scenario

There are some aspects which have to be considered when offering mobile services in a vehicle:

- The vehicle Human Machine Interface (HMI) should be used to minimize distraction and to make use of the optimal resources.

- A travel destination (coming from a navigation system) might be used for input instead of the current location (provided e.g. by a GPS receiver or the localisation service of a GSM provider).

- Further data may be available to optimize the service (e.g. ETA, estimated time of arrival).

- Vehicle hardware may be used to enhance the service (e.g. feeding the target address into the navigation system).

The hardware / software set-up needed to install such a LBS service in a vehicle is shown, for illustration, schematically in figure 2.

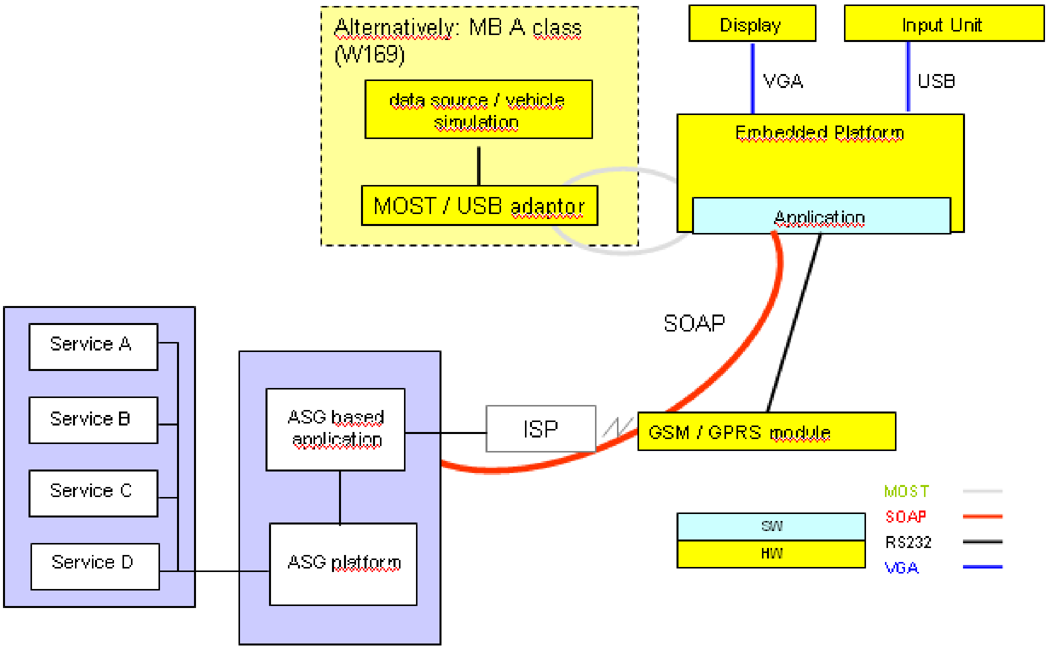


Figure 2: Hardware / Software set up for installing a location-based service in a car.

This scenario addresses both the dynamic service interface, the mobile interface and the user related service requirements. Similar requirements for service delivery are expected to be found in other mobile/wireless environments.

3. From Web Services towards Semantic Web Services

3.1 Evolution to future service provisioning

Personalisation is one of the most important characteristics service provisioning in future telecommunication systems. Personalisation means tailoring of services and applications to the very specific needs of a user to a ubiquitous comfortable service environment together with a single bill service independent of the partners involved in the end to end value chain. Personalisation also means to allow fully manual service configuration, carrier access without any automatic vertical handover procedures and individual invoicing of the individual service partners, in case this is required by any user for any reasons.
Market participants face the following trends:

- Content and services are distributed across domains including fixed line and mobile networks as well as open (e.g., world wide web) and closed service environments. Business relations might be distributed.
- Internet services are mainly used by fixed line access, whereas more and more initiatives are evolving to provide Internet services through wireless rather than mobile access.
- Technology evolution separates call control and transport. The directions of centralise or spread out of the service control are regarded as a chance and a threat for mobile operators.

- Transport charges are dropping tremendously due to excessive IP transport capacities in back-bone networks and due to increased competition in access networks (flat rates).
- There is a strong impact of IT technologies on telecommunications protocols, system design and interfaces. Convergence is not longer restricted to the protocol layer, but addresses the whole value chain.
- Semantics have entered the business world, e.g. Enterprise Service Architecture (ESA) by SAP and Microsoft, and will influence the service provision platform of mobile operators.
- A growing importance of peer to peer services integrates the single user into the group of service and application providers.
- An increasing importance of ubiquitous computing technologies (sensor networks, RFID, NFC) leads to pervasive interaction with service systems and provide new possibilities for services based on rich information.
- Trust in context aware services still suffers from privacy concerns of the users. In addition legal aspects do also restrict providers in offering rich context aware services.

These aspects lead to following conclusions:

- Users will maintain several business relations in different service domains.
- Access procedures including authentication and authorisation will become more and more complex and will happen more often.
- IP based services will dominate.
- Service control is not per definition in the domain of the telecommunication operator.
- Telecommunication network operators can hardly survive by providing bit pipes only. Value added services are a prerequisite for future business of telecommunication operators. Mobile network operators have to identify their unique selling points and to force them into the market.
- A trusted position in the market is important for the acceptance by the users.

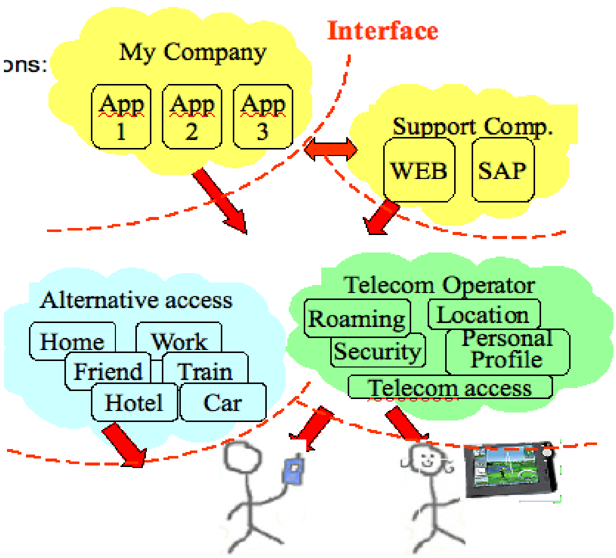


Figure 3: Multi domain network and service environment

Figure 3 illustrates our vision of a multi domain network and service environment. Mobile services platforms of telecommunication providers and mobile operators in parallel to 3rd party service environments provide service through application servers to the customers. Additional functionalities, e.g., identity manager or billing, are depicted as separate functions that may be provided also by 3rd parties.

3.2 Semantic Web

The semantic web is an evolving extension of the World Wide Web in which web content can be expressed not only in natural language, but also in a form that can be understood, interpreted and used by software agents, thus permitting them to find, share and integrate information more easily [Wikipedia, 2007]. The Web is not longer just a medium for human-readable information, but evolves to the Web as a universal medium for data, information, and knowledge exchange. Ontologies are introduced to support the understanding of terms used in the Web.

3.2.1 Ontologies

In order to enable the meaningful communication between different service components a common understanding of used terms and definitions need to be achieved. But as there is no global common understanding and use of terms this understanding needs to be established between communicating parties on the fly. In order to enable this mechanism, semantic descriptions, using taxonomies and ontologies need to be used.

Ontologies are for **knowledge sharing and reuse**, while languages such as XML are perfect to **express information** in a **structured and efficient way**. To be able to discuss with one another, communicating parties need to share a common terminology and meaning of the terms used. Otherwise, profitable communication is infeasible because of lack of shared understanding. With software systems, this is especially true—two applications cannot interact with each other without common understanding of terms used in the communication. Until now, this common understanding has been achieved awkwardly by hard-coding this information into applications. This is where ontologies come into the picture. Ontologies describe the concepts and their relationships—with different levels of formality—in a domain of discourse. An ontology is more than just a taxonomy (classification of terms) since it can include richer relationships between defined terms. For some applications, a taxonomy can be enough, but without rich relationships between terms it is not possible to express domain-specific knowledge except by defining new terms.

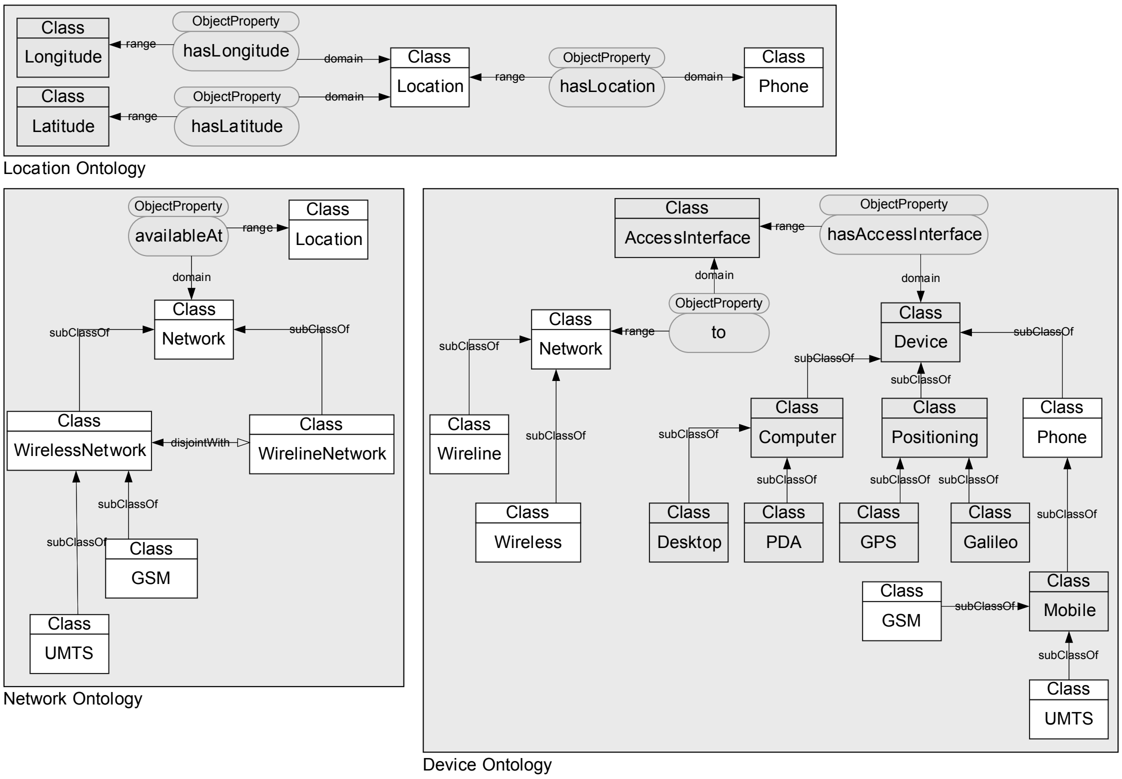


Figure 4: An example ontology for devices, networks and locations

Ontologies have been an active research area for a long time. The hardest issue in developing ontologies is the actual conceptualisation of the domain. Additionally, to be shared, the ontologies need a representation language. Languages like XML that define the structure of a document, but lack a semantic model, are not enough for describing ontologies —intuitively an XML document may be clear, but computers lack the intuition.

In recent years various ontology languages based on Web technologies have been introduced, the two main ones being OWL and WSML. DAML+OIL, which is based on RDF Schema [RDF2006], is one such language. It provides a basic infrastructure that allows machines to make simple inferences. Recently, DAML+OIL language was adopted by W3C, which is developing a Web Ontology Language (OWL) [OWL2006] based on DAML+OIL [OWL-S]. Like DAML+OIL, OWL is based on RDF Schema, but both of these languages provide additional vocabulary—for example relations between classes, cardinality, equality, richer typing of properties, characteristics of properties, and enumerated classes—along with a formal semantic to facilitate greater machine readability. The OWL language has a quite strong industry support, and therefore it is expected to become a dominant ontology language for Semantic Web. Figure 4 provides example ontologies for devices. networks and locations.

Ontologies are the key components in semantic service provision. Key issues in ontology creation are the complexity of the ontologies and how to enable interworking between different ontologies. Creating one main ontology covering user goals, service platform capabilities and service capabilities would make interworking easier, but will result in a complex and hard to handle ontology. When distributing the ontologies into service ontologies, user goal ontologies and platform ontologies one needs to address interworking, called mediation of ontologies.

3.2.2Mobile Ontology: Ontology Adoption for Mobile Services

Mobile environments and the Web converge forming a shared Distributed Communication Sphere (DCS). This causes the appearance of new settings to be supported, e.g., when the user utilizes mobile and fixed devices to interact with systems. Interaction and connectivity of mobile applications with the Internet services will become a substantial service offer in the mobile world. To ensure interoperation of mobile and Web services, applications and tools (running on heterogeneous various service platforms in such a sphere), developers need to have a shared specification of objects belonging to the sphere and their roles. Certain ontologies have already been developed for the mobile communications domain by employing area with employment of Semantic Web formalisms [Korpipää et al., 2004; Pfoser et al., 2002]. However, widespread and global adoption of such ontologies remains a challenge.

A Mobile Ontology is being developed as a comprehensive "higher-level" ontology for mobile communication domain. The ontology is a machine readable schema intended for sharing knowledge and exchanging information both across people and across services/applications, and it covers domains related to mobile communications, specifically, addressing persons, terminals, services, networks [SPICE D 3.1, 2006]. Currently, definition and implementation of this Mobile ontology is managed as a collaborative effort amongst participants of the EU IST SPICE Integrated Project[1].

The added values of a Mobile Ontology are:

- Providing an easy and formal way to reference objects from the mobile communications domain (in particular, to serve as an exchange format between mobile service enablers);
- Providing an opportunity to implement enhanced, ontology-based reasoning;
- Providing a formal representation of the domain to be used in research and development projects, and for educational purposes.

The Mobile Ontology as developed in the SPICE project covers basic communication terms, characterisation of the user, terminals and networks, as well as service specifications. The ontologies were developed using RDF and OWL [RDF, 2006; OWL, 2006]. It reuses existing ontologies as UAProf from the Open Mobile Alliance (OMA), FOAF from the foaf-project and vCards from W3C.

[1] SPICE: http://www.ist-spice.org/

3.3 Semantic Web Services

To develop and maintain services for the future that are both attractive, easy to use and cheap enough developers have realized that new methodologies, techniques and tools are necessary. Based on these facts concepts and technologies like Service Oriented Architectures (SOA), Web Services (WS), Semantic Web (SW) and Semantic Web Services (SWS) have gradually grown up to show their viability, especially if they are used in combination. Ongoing work in standardization bodies (e.g. W3C and OASIS) and research forums (e.g. EU IST FP 6) supports these developments. The ASG (Adaptive Service Grid) and the SPICE projects are typical examples of EU projects that have as goals to utilizing concepts and technologies from SOA, WS, SW and SWS and demonstrates their maturity by developing services within selected business domains. All major software vendors have already adopted Web Service (WS) technology, i.e. WSDL (Web Services Description Language), SOAP (Simple Object Access Protocol) and UDDI (Universal Description, Discovery and Integration) to be a corner-stone in their future tools for service creation. They move to SWS to meet the requirements of future enterprise systems; to create and execute in near real-time and cope with context awareness, personalization and mobility. SWS adds extra semantics to the service descriptions enabling WS to work together more flexible, intelligent and automatic.

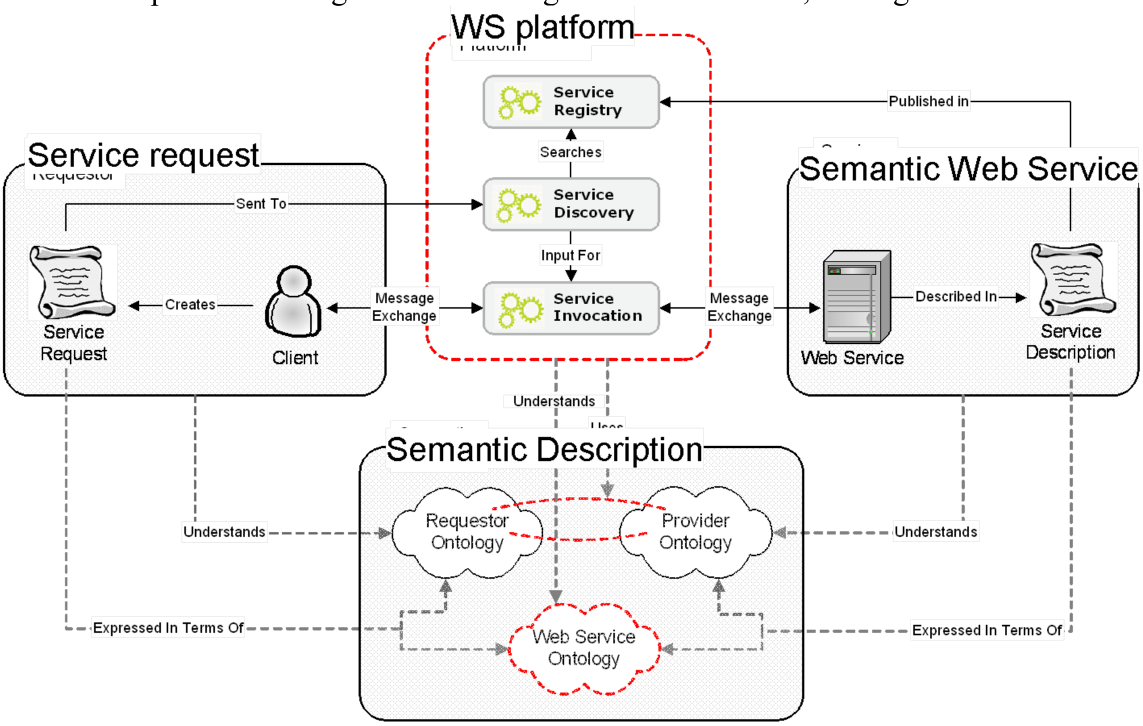


Figure 5 - Elements involve in Semantic Web Service delivery

There are two major approaches in how to extend WS to SWS, as indicated in figure 5. Most approaches like OWL-S, WSMO and SWSF create a SWS description language, and then map it to the Web service. WSDL-S, SAWSDL on the other hand annotates directly the WSDL file and defines semantics as part of the file.

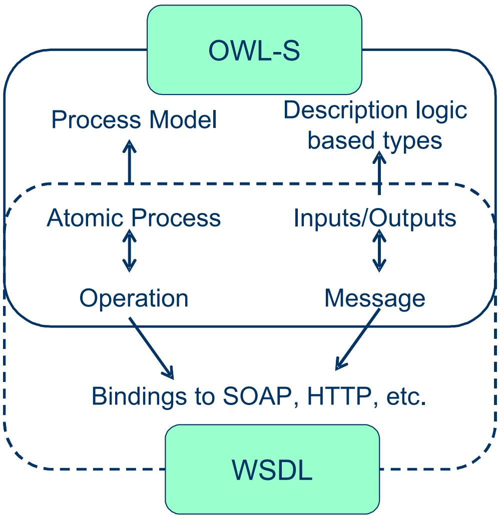
The terminology used in SWS is recalled here: **XML** provides a syntax for structured documents, but imposes no semantic constraints on the meaning of these documents. **XML Schema** is a language for restricting the structure of XML documents and also extends XML with data types, which might be seen as a first step to add Semantics. **RDF** is a data model for objects ("resources") and relations between them, provides a simple semantics for this data model, and these data models can be represented in XML syntax. **RDF Schema** is a vocabulary for describing properties and classes of RDF resources, with a semantics for generalization-hierarchies of such properties and classes [OWL2004]. This chapter will describe the basic relationships, a detailed description of the semantic web services approaches OWL-S, WSMO, WSDL-S, SWSF and SAWSDL are found in the W3C submissions and related documents [OWL-S], [OWL-S 1.1], [Ontobroker], [SAWSDL] [SWSF], [SWSO], [Bruijn05], [WSMO].

3.3.1 Web Ontology Language for Services (OWL-S)

OWL-S, former DAML-S is an OWL-based Web Service Ontology [OWL-S 1.1], with first specifications names *DAML-S 0.5* back in 2001. It provides a core set of markup language constructs for describing properties and capabilities of their Web services in a computer-interpretable form. It is the first well-researched Web Service Ontology, and as such the reference for all further developments.

OWL-S provides a semantic view of the service through a profile. The link to WS or other type of service is called *grounding*. Figure 6 provides the formal mapping between the OWL-S described ontology and the WSDL described Web Service. It subdivides between the operation/process of the service, and the input/output from the services. The process is described through a process model, while the input/output is described through types.

Figure 6 - Formal Mapping of OWL-S to Web Services (WS)



OWL adds more vocabulary for describing properties and classes: among others, relations between classes (e.g. disjointness), cardinality (e.g. "exactly one"), equality, richer typing of properties, characteristics of properties (e.g. symmetry), and enumerated classes.

OWL-S is quite complex for a non-expert to understand. It needs tools like OWL-S API and WSDL2OWL, which currently have some severe limitations. A more principle criticism is that OWL-S focusses only on one ontology, it should allow multiple parameters mapping to one syntactic parameter.

3.3.2 Web Services Semantics (WSDL-S)

WSDL-S, submitted to the W3C by IBM on 1 October 2005 [WSDL-S], is using the Extensibility Elements of WSDL 2.0 [WSDL 2.0], i.e. semantic annotations are added to the WSDL document elements that have constructs to represent service descriptions like interface, operation, message, binding, service and endpoint. The first three, namely interface, operation and message constructs deal with the abstract definition of a service while the remaining three (binding, service and endpoint constructs) deals with service implementation. The WSDL-S proposal focusses on semantically annotating the abstract definition of a service to enable dynamic discovery, composition and invocation of services.

WSDL-S defines a Semantic Model to capture the terms and concepts used to describe and represent the Web service. WSDL-S uses the extensibility of WSDL. Four particular parts of the semantic model are distinguished:

- Input Semantics – the meaning of input parameters
- Output Semantics – the meaning of output parameters
- Precondition – a set of semantic statements that are required to be true before an operation can be successfully invoked
- Effect – a set of semantic statements that must be true after an operation completes execution after being invoked. Different effects can be true depending on whether the operation completed successfully or unsuccessfully.

Semantic annotation in WS descriptions is an obvious first step in bridging Web services with Semantic Web technologies. It relies on both the WSDL and XML schema extension mechanisms to reference external semantic models. It is a lightweight approach extending WSDL files with semantic annotations. WSDL-S is independent of any particular semantic annotation language, examples of which include WSMO and OWL-S.

The lightweight approach makes WSDL-S easy to handle. But it does not support mapping of many semantic parameters to one web service parameter, as it is restricted to the principle mechanisms of WEB Services, mainly to achieve a result specific to one service. Main criticism is that it is too flexible with respect to model, script and rule language. Thus values of semantic parameters are not always identical to values of syntactic parameters.

3.3.3 Semantic Web Services Framework (SWSF)

SWSF was submitted to W3C by National Institute of Standards and Technology (NIST), National Research Council of Canada, SRI International, Stanford University, Toshiba Corporation, and University of Southampton on 9 September 2005 [SWSF].

SWSF includes the Semantic Web Services Language (SWSL) and the Semantic Web Services Ontology (SWSO) [SWSL], [SWSO]. It builds on the WSDL (v1.1), and extends through supporting the specification of work flows composed of basic services. A promising candidate is the Business Process Execution Language for Web Services (BPEL4WS). The second focus is on the choreography, the information exchange and agreed ordering rules to perform a Web service-based transaction. With respect to registering Web services for purposes of advertising and discovery, SWSF will build on UDDI.

FLOWS, the ontology of service concepts used in SWSF, is a more comprehensive ontology as compared to OWL-S. In terms of coverage it is distinguished by its axiomatizing of messages, something that was not addressed in OWL-S. Both attempt to provide an ontology for Web services, but FLOWS had the additional objective of acting as a focal point for interoperability, enabling other business process modelling languages to be expressed or related to FLOWS.

3.3.4Web Service Modelling Ontology (WSMO)

WSMO was submitted to W3C by DERI Innsbruck at the Leopold-Franzens-Universität Innsbruck, Austria, DERI Galway at the National University of Ireland, Galway, Ireland, BT, The Open University, and SAP AG on 04 April 2005 [WSMO].

WSMO (Web Service Model Ontology) uses WSMF's (Web Service Modelling Framework) four elements for describing semantic Web Service [Bruijn05] :
- Ontologies for terminology used by other elements
- Goals is the definition of the problem the Web services is to solve
- Web Services descriptions that define different aspects of a Web Service
- Mediators handle interoperability of other ontologies.

These four are syntactical modelled by WSML (Web Service Modelling Language).

WSDL is a form of syntactical contract by specifying the format of the messages sent between the web service and the client. In contrast, WSMO describes functionality and behaviour of the Web Service. The descriptions are for discovering and automatic composition of Web services. The UDDI registry for WSDL specifications are based on keywords. WSMO discovery uses the semantics in the WSMO description of a web service. WSMO can be located in UDDI registers, but it is more effective to have a specific WSMO repository as in the ASG platform.

3.3.5 SAWSDL

SAWSDL (Semantic Annotations for WSDL) specification [SAWSDL] defines a set of extension attributes for the Web Services Description Language [WSDL 2.0], that allow to describe additional semantics of WSDL components such as input and output message structures, interfaces and operations. This specification does not address the annotation of WSDL components that deal with service implementations e.g. binding, service and endpoint.

SAWSDL specification defines how semantic annotation is accomplished using references to semantic models, e.g. ontologies. SAWSDL does not specify a language for representing the semantic models. Instead it provides mechanisms by which concepts from the semantic models, typically defined outside the WSDL document, can be referenced from within WSDL components using annotations. To accomplish semantic annotation, SAWSDL defines extension attributes that can be applied both to WSDL elements and to XML Schema elements. The annotations on schema types can be used during Web service discovery and composition. In addition, SAWSDL defines an annotation mechanism for specifying the structural mapping of XML Schema types to and from an ontology such mappings could be used during invocation, particularly when mediation is required.

3.3.6 Comparison of approaches

The following comparisons will provide a high level view on the approaches, with the specific focus on usability for end-users. Further details and indepth discussions are ongoing in W3C and other fora. The OASIS SEE TC and the W3C SAWSDL WG initiative can be seen as the promising attempts to standardise Semantic Web Services technologies. SAWSDL attempts to provide an overlay for semantic annotations, thus allowing various approaches to be compared with each other [Dorner2006].

WSMO versus SWSF

WSMO is a parallel effort to SWSF and base its work on almost the same fundamental technologies, e.g on F-logic. Nevertheless, the two groups have pursued complimentary goals. WSMO has focused heavily on the language effort. In particular to develop a "conceptual syntax" for top-level descriptions of services; this might make the specifications easier to read for the end user. WSMO has also paid special attention to the issue of OWL compatibility.

The major distinction between the WSMO effort and the SWSF is with respect to the ontology domain. WSMO is focusing on describing Web service choreography through guarded transition rules, while SWSF focusses on extending the functionality of the rule language (SWSL-Rules) that supports meta-reasoning and reification extensions.

WSDL-S versus WSMO

In WSDL-S, the semantic model of a Web service is expected to contain the semantics of input and output parameters and the specifications of preconditions and effects of service operations, plus the categorization of a WSDL interface. WSMO specifies a more detailed model where a Web service can have a capability with preconditions, assumptions, postconditions and effects; and an interface with choreography and orchestration; and where data are described using ontologies.

WSDL-S is based on the WSDL model of Web services interfaces consisting of separate operations, and preconditions and effects in WSDL-S are attached to operations. In contrast, WSMO distinguishes between preconditions, assumptions, postconditions and effects, but these aspects are modeled on the whole Web service. WSMO talks about a Web service as a whole, without splitting it to operations. Additionally, WSMO models the choreography and orchestration interface(s) of a Web service, an aspect not covered by WSDL-S at all.

SAWSDL

SAWSDL specification is currently a W3C working draft, established in March 2006 by the various actors in order to not let interoperability problems between the approaches hamper the development of semantic web services.

4. Challenges

Despite significant developments and breakthroughs, there are challenges in semantic service realisations especially in today's distributed and complex service world. This chapter is going to illustrate the challenges in service integration through inter-working of standards and mediation of ontologies. While service interworking is one issue, user related aspects like security and privacy of private information in distributed ontologies is another aspect. These issues are addressed in section 4.1. Growing popularity of mobile services demands attention in the context of semantic service delivery to mobile devices. This is challenging considering the limited resources and capabilities of mobile environment. Section 4.2 discusses these challenges from context-aware service delivery and privacy and identity handling point of views.

From the evaluation of the existing and upcoming technologies, WG2 concludes that

- Evolution to future service provision will happen through Semantic Services
- Semantic service descriptions will
  - allow a dynamic service composition
  - ease complex services to consist of distributed services components
  - enable service component interactions
  - provide service life cycle support
  - enable preference description and supports adaptation to interests
  - support personalisation and context awareness (cc/pp, UAprof,...)

An industrial uptake of semantic technologies is hampered by non-user friendly tools, which have mainly been developed in academic groups. Focus for further tool development should be to help ordinary users to establish both ontologies and service engines.

The major challenge in mobile semantic service provision comes from the mobile/wireless environment, which is not a SOA environment. The following features have to be taken into consideration to let Semantic Services become the platform for mobile services.

- Interfaces between the SOA based architecture and the mobile phone need to be adapted in order to cope with the radio environment.
- Proximity and phone services need to be integrated into the service architecture.
- Radio and context awareness of service provision, taking into account the highly variable radio environment.

4.1 Service Realisation and Expectations

Future service access is based on interworking between different service modules, a distributed service infrastructure and user aspects like context awareness. While semantic interworking within a part of a system, e.g. one service platform, is becoming reality, interworking between different users, services and service provisioning engines is still a major challenge.

4.1.1 Semantic service architecture interfaces

Semantic service provisioning will happen through a variety of systems, and has to take into account user and service aspects. Even though most of them might be represented in a semantic way, there will be service components which are not or cannot be semantically described. An example of such components are sensors or sensor nodes, which have limited capabilities and thus will only provide a minimum set of communication and sensing capabilities. It is also questionable whether mobile phones will allow memory-, cpu- and battery-consuming applications to be implemented on the phone. Time-critical applications might also require a specific interface.

Thus we expect that semantic systems will have to work together with non-semantic systems, and that this requires an architecture which is beyond the current developments in semantic services delivery.

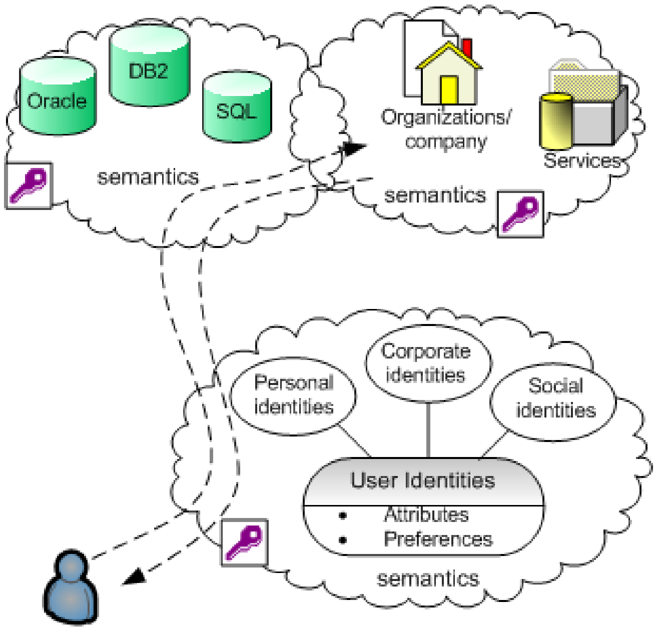


Figure 7: Semantics used for identity handling and personalisation of services

4.1.2 Mediation of ontologies

Even in a system where all components are implemented in a semantic way, the underlying ontology will not be the same. Ontologies are expected to be developed for specific purposes, with contributions from many different persons and organizations. Because of the distributed and open nature of the Web, these ontologies can be expected to contain conflicts and semantic overlap; different ontologies would describe (parts of) the same domain in a different way, because of differences in the point of view of the different people who have developed the ontologies. The worldwide ontologies or 'swamp of ontologies' contain the conflict of interoperability because of the problems of granularity, understanding and trust. Mediation of ontologies is a first step in understanding the concepts and relations, but does not take into consideration the background of people who created them.

There are different aspects in the interoperability of applications on the Semantic Web. In order to achieve interoperability between applications, data needs to be exchanged. This data needs to be interpreted by the receiver in the way it was intended by the sender. Let us take the example of Telecom world. From customer's point of view, quality-of-experience means 'how long it takes to set-up a call' or 'the delay experience when talking'. Service operators mediated these quality-of-experience requirements through a set of QoS parameters establishing a minimum standard. Finally network operators respond these requirements by mapping QoS parameters into network parameters through setting priority routes, parameters of handovers. Thus a different understanding of words need to be taken into consideration when enabling mediation of ontologies. Figure 7 illustrates the semantics distributed in service world both from user's and service providers point of view.

Ontologies can help in the interpretation of data through formal and explicit representation of data, which can help machines to interpret data. Having ontologies is not enough to achieve full interoperability between applications, because of the differences in the ontologies used by various applications. The use of different ontologies and the reconciliation of differences between ontologies is called *ontology mediation*.

Ontology mediation establishes explicitly the relationships between different ontologies. Applications that use different ontologies will be able to interpret data that has been described in terms of an ontology which is not known to the application, but which has been formally related to an ontology which is known to the application.

4.1.3 Industry standards

De-facto industry standards have been published by industrial players like IBM, SAP, Microsoft, Oracle. One of the open standards-based integration platforms is the Java Business Integration (JBI)[2] architecture. This standard extends J2EE and J2SE with business integration Service Programming Interfaces (SPIs). These SPIs enable the creation of a Java business integration environment for specifications such as WSCI, BPEL4WS and the W3C Choreography Working Group.
Figure 8 shows the JBI high level architecture. It leaves more freedom to platform providers as there is a limited number of mandatory components. Additional components can be integrated using a generic SPI mechanism. The standard was established in the end of 2006, and is subject to prototypical implementation.

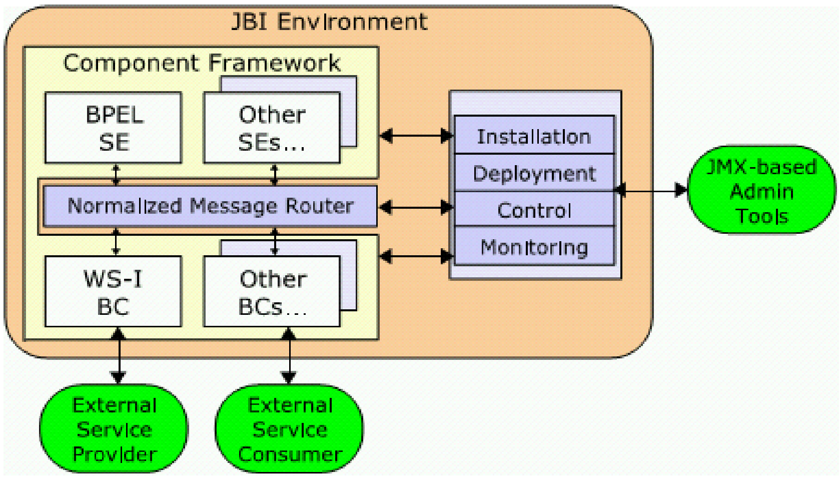


Figure 8: Top-level view of the Java Business Integration (JBI) architecture

4.1.4 Other semantic web service implementations

There are also other frameworks and reference implementations for Semantic Web Services available. Most notable of these are WSMX, IRS-III and Meteor-S [ASG D7.IV, 2006].
WSMX[3] (Web Service Modelling eXecution environment) is a reference implementation of WSMO[4]. The aim of WSMX is to increase business processes automation in a very flexible manner while providing scalable integration solutions. WSMX internal language is WSML[5] (Web Service Modelling Language). WSMO and WSML specifications together with WSMX

[2] http://java.sun.com/integration/
[3] http://www.wsmx.org/
[4] http://www.wsmo.org/
[5] http://www.wsmo.org/wsml/

environment are developed by DERI International under ESSI[6] cluster (formerly SDK cluster).
METEOR-S is a follow in project to METEOR project, which focused on workflow management techniques for transactional workflows at the LSDIS Lab[7], University of Georgia. METEOR-S addresses “Web-based business processes with the context of Service Oriented Architecture (SOA) and the semantic Web technologies and standards. METEOR-S attempts to build upon existing SOA and Semantic Web standards whenever possible (using extensibility features) and where appropriate, propose extensions to or seek to influence to existing standards.”
The Internet Reasoning Service - IRS - is KMi's[8] Semantic Web Services framework, which allows applications to semantically describe and execute Web services. The IRS supports the provision of semantic reasoning services within the context of the Semantic Web. There are currently two implementations: IRS-II and IRS-III, which have been applied within different projects. IRS-II follows the UPML framework while IRS-III is a platform and infrastructure for creating WSMO-based Semantic Web Services, building upon the previous implementation, IRS-II.

4.1.5 Semantic support for user centric services

For mobile service provisioning service adaptation to user preferences, the user context and the communication capabilities of the user is mandatory. The radio environment might be limited, or the user might not want to be overloaded by content. Enabling the service environment to get the user context will help to just send the information suitable for the current context of the user. One potential approach is to associate roles with the user, and thus adopt the service offer to the role of the user in the current situation. Examples of these roles are a user being 'project leader' in a corporate environment, and 'father' or 'soccer trainer' in a social setting.

Based on these roles the user will receive relevant information and get access to resources. The access provisions to resources might have differential privileges which can be termed as policy. Identity management and privacy assurance can be achieved by semantically defined roles, policies and rules.

The introduction of semantics and the representation in RDF and XML allows describing user preferences and relations to characterize the community context. The challenge is to extend Semantic Web Services with policies, representing security requirements for service discovery and privacy protection of user requests. Secure service interaction requires access control and privacy protection. This is more crucial in a community or group environment. Semantic web technology can introduce a formal way to represent roles, policies and rules to provide access control and privacy services in identity management of corporate and social community environment. A semantic service architecture may be composed by distributed ontologies based on these roles, policies and rules. Each Role has a certain policy (or policies). A policy represents the privilege reserved for each role in a community and expressed through a set of rules. It is such ‘when an individual is not being authenticated as a member/leader of a project, then he/she is a visitor’. It is a challenge for semantic web community to handle access control and privacy issues using ontology describing roles, policies and rules. Maintaining security of these ontologies is also a crucial issue in a distributed and open web environment.

4.2 Mobile Semantic Services

[6] http://www.essi-cluster.org/
[7] http://lsdis.cs.uga.edu/
[8] http://kmi.open.ac.uk/

Mobile Semantic Services will have to focus on the commonalities and differences in a user-centric (or I-centric) and service centric approach. The difference between both approaches is historical, where a service centric architecture was introduced to let services communicate with each other. The I-centric approach of WWRF is based on the transition of access delivery to user focussed service delivery [Kellerer2002].

4.2.1 Personalisation and context aware services

The mobile service world has made the move to a SOA oriented architecture. Most of the mobile services like location information are available through a Parlay X Web service interface [3GPP2003]. Noll et. al. established a semantic annotations of advanced Telecom services to achieve exchange of roaming information on a dynamic basis. The main findings of the approach were the cost reductions in service delivery, due to reduced effort for testing and updating of Web services in a semantic service world [Noll2006b].

Two issues remain unsolved when it comes to the usage of SOA in a mobile environment, *(i)* the variation of the radio quality and (ii) specific mobile services in the proximity of the user [Noll2006d]. Radio is a shared resource, and the quality of the radio link is affected by user mobility, radio environment (user speed and coverage radius), application topology, and user terminal requirements. A service oriented platform builds on reliable, minimum delay and high-bandwidth connectivity, which is not achievable in mobile/wireless environments. A proxy can be set as an interface between service oriented architecture and the mobile world. Such a proxy might function as a virtual phone in the network, and will just exchange the necessary information between the "virtual phone", as seen by the service world, and the real phone in the rough radio environment.

Current rule-based algorithms become too complex when handling user context and preferences, thus asking for new mechanisms allowing dynamic adaptability of services. The service world of a mobile/wireless user consists of proximity and remote services. Examples of proximity services are admittance services or payment through contact-less cards. These services are moved to the mobile phone through Near Field Communications (NFC) and prototyped world-wide, e.g. from Mastercard in Dallas. One goal of these field trials is to demonstrate interworking between wireless technologies and NFC, another goal is to address security issues like potential threats, identity, privacy and simplicity. Adding NFC capabilities to the mobile phone opens for key exchange through near field and through the mobile network, thus providing a principle way of delivering authentication information.

4.2.2 Conclusions for semantically supported mobile services

Identity handling is crucial when the mobile service world is moving toward SOA. The user will be available (and traceable) 24 hours-a-day, and electronic transactions initiated from the phone might become a source of surveillance. Thus protection of the user's privacy and identity will become a key issue. The SIM card of mobile phone is having the potential to serve as the user's secure identity handling terminal. Current interfaces between the SIM card, the mobile phone and the supporting mobile network are optimized for speed and minimum consumption of radio resources.

Considering the fact that 'the mobile is optimized' from a resource point of view, while semantic services are optimized for service creation, composition and delivery, shows the need for adaptation of semantic services towards the mobile environment. A semantic service has a lot to offer for efficient identity handling and privacy assurance. But it does not satisfy the mobile constraints. Some research suggests having a 'virtual phone' in the network might be a potential way of dealing with the constraints of the radio environment.

The service centric world was introduced based on service level agreements (SLA) between trusted partners. In a more dynamic service provisioning world, as envisaged in a Semantic Web Services environment, privacy and security become key issues. WWRF WG2 follows the approach to take advantage of developments in both worlds, using the security and privacy mechanisms of the I-centric world and combine them with the semantic representation of data as known from the Semantic Web (Services) World. In the I-centric world security and privacy are important. Based on user preferences and context handling, connections between different services could be tracked. In current mobile systems privacy is addressed as network operators don't send user information like MSISDN to service providers. The current usage of “open” ontologies does not support privacy. With a system which is handling the users environment inside its private area (phone, laptop etc.), a malicious tracking software could easily track the user and thus compromise the user’s online life.

5. Business Considerations

While prototypical implementations of semantic services are well under way, only a limited number of studies have addressed the business qualitatively. ASG project members from DaimlerChrysler, Telenor and Polish Telecom have performed an estimation of the business profitability of semantic web services [ASG D7.IV, 2006],[Noll2006b]. They used a methodology for measuring the costs of semantic services provision, based on an ASG architecture implementations of the mobile traveller scenario. The manpower estimates provided in this example are based on the effort analysis used to implement location based services in the operational networks of Telenor and TP/Orange.
Analysing the business of providing advanced services for the mobile user is based on the following steps:

1) Create a service overview, here addressing services for the mobile user, including location information, routing, points-of-interest (POI) and booking of a service.

2) Identify real world services, here the location services from Telenor and Orange and make them available as Web services.

3) Establish the methodology to convert the existing Web services to semantic web services, and make them available in an application. Our methodology is based on the three areas:

    - Svc: The Semantic Service Creation, including semantic description of the service, service testing and registration at the service platform.

    - Dmn: Domain Ontology development, required for defining the service landscape semantically.

    - App: The End-user Application, which is the interface for real users to address the services.

Addressing the life time of a product means analysing the costs/effort it takes to establish a service, to maintain the service and to modify/upgrade a service. Our analysis aims in comparing conventional services with semantic web services. The efforts in person days (pd) per step are estimated efforts based on the experiences from the implementation of semantic based location services. The usage of semantics for services incorporates the following changes:

- Svc Service creation: We assume that services are available as Web services, and thus the main effort is to establish a semantic service description.

- Svc - Service testing is easier in a semantic web service environment, as a testing suite has to be written only once, and can be used for all testing of all services.
- Svc - Service registration is of similar effort for conventional and semantically based services.

Table 1: Semantic service provision compared to conventional service provisioning

Description	Provider A		Provider B		
	Serv. p [pd]	Serv. q [pd]	Serv. p [pd]	Serv. q [pd]	Conv. Serv.
Svc – Semantic description	20	4	5	2	0
Svc – testing	3	0	1	0	4
Svc – registration	3	2	1	1	2
Dmn – creation/update	30	3	4	1	0
App – not considered	-	-	-	-	-

- Dmn - Domain ontology development is only needed for SWS, and is a clear cost driver.
- App - application development is not considered now, but is subject to further work.

The study used the deducted effort for semantic service delivery, and apply them to two service providers with up to 5 services each. As expected, initial semantic service description for SWS drives the costs. For one service provider the advantages of using SWS are in the easier testing and upgrade of services, but required efforts in semantic service creation and domain ontology development drive the costs. If we include the domain ontology development and update, we receive the manpower estimations of Figure 9. The figure shows that the development of the semantic service description and the domain ontology are the cost driver for the first provider. A second provider will only see incremental costs for the domain ontology adaptation. He will already see cost benefits when providing 5 services.

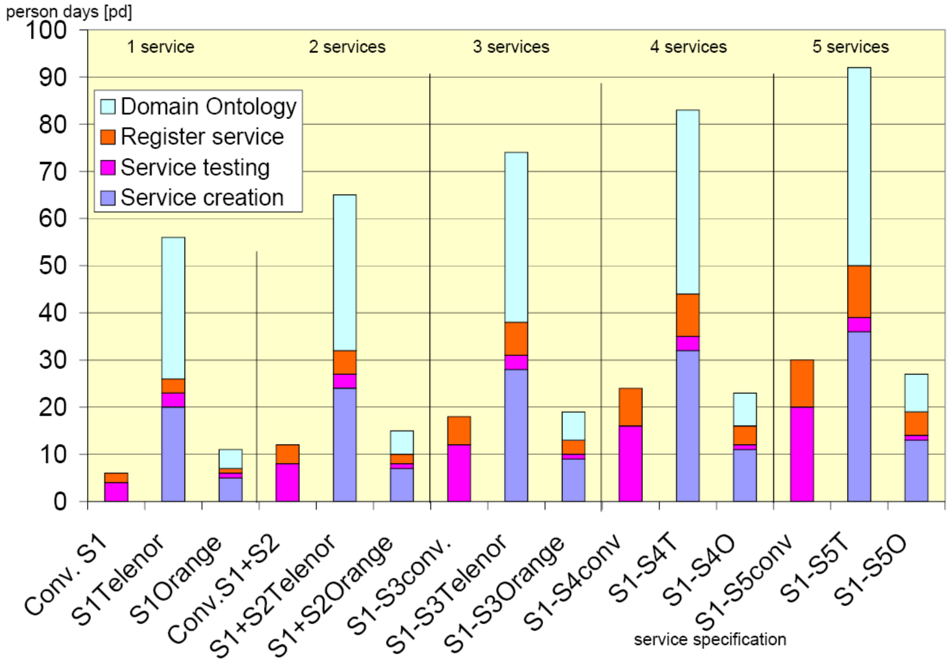


Figure 9: Costs of service creation, registration, testing and ontology creation

When calculating just service related costs between conventional and SWS delivery, a break even point would be achieved for 3 providers with 5 services, or 5 providers with 3 services. However, including domain ontology will move the break even point to higher values (right fig.) with 15 services provided from 5 different providers.

When including the update of service, the break-even point will be reached for substantially lower number of providers or services. Thus, service maintenance and service upgrade are the items which make SWS delivery advantageous as compared to conventional service delivery.

6. Summary and Outlook

The semantic web is an evolving extension of the World Wide Web in which web content can be expressed not only in natural language, but also in a form that can be understood, interpreted and used by software agents, thus permitting them to find, share and integrate information more easily. Concepts and technologies like Service Oriented Architectures (SOA), Web Services (WS), Semantic Web (SW) and Semantic Web Services (SWS) have gradually grown up to show their viability, especially if they are used in combination. Most approaches like OWL-S, WSMO and SWSF create a SWS description language, and then map it to the Web service.

The paper presents the basics of the semantic web services approaches OWL-S, WSMO, WSDL-S, SWSF and SAWSDL. WSDL-S, submitted to the W3C by IBM on 1 October 2005, is using the Extensibility Elements of WSDL 2.0, i.e. semantic annotations are added to the WSDL document elements that have constructs to represent service descriptions like interface, operation, message, binding, service and endpoint. It does not support mapping of many semantic parameters to one web service parameter, as it is restricted it to the principle mechanisms of WEB Services, mainly to achieve a result specific to one service. SWSF was submitted to W3C by National Institute of Standards and Technology (NIST), National

Research Council of Canada, SRI International, Stanford University, Toshiba Corporation, and University of Southampton on 9 September 2005. SWSF includes the Semantic Web Services Language (SWSL) and the Semantic Web Services Ontology (SWSO). WSMO (Web Service Model Ontology) uses WSMF's (Web Service Modelling Framework) four elements for describing semantic Web Services: Ontologies for terminology used by other elements, Goals are the definition of the problem the Web services have to solve, Web Services descriptions that define different aspects of a Web Service, and Mediators to handle interoperability of other ontologies. SAWSDL (Semantic Annotations for WSDL) specification defines a set of extension attributes for the Web Services Description Language (WSDL), that allow to describe additional semantics of WSDL components such as input and output message structures, interfaces and operations.

Semantic service descriptions will allow a dynamic service composition, ease complex services to consist of distributed services components, enable service component interactions, provide service life cycle support, enable preference description, supports adaptation to interests, and supports personalisation and context awareness. Semantic descriptions are based on ontologies, which are expected to be developed for specific purposes, with contributions from different people and organizations. Because of the distributed and open nature of the Web, these ontologies can be expected to contain conflicts and semantic overlap; different ontologies would describe (parts of) the same domain in a different way, because of differences in the point of view of the different people who have developed the ontologies. The worldwide ontologies or 'swamp of ontologies' are potential sources for interoperability because of the problems of granularity, understanding and trust.

De-facto industry standards have been published by industrial players like IBM, SAP, Microsoft, Oracle. One of the open standards-based integration platforms is the Java Business Integration (JBI) architecture. This standard extends J2EE and J2SE with business integration Service Programming Interfaces (SPIs). A widespread uptake of semantic technologies is currently hampered by non-user friendly tools, which have mainly been developed in academic groups. Focus for further tool development should be to help ordinary users to establish both ontologies and service engines.

The major challenge in mobile semantic service provision comes from the mobile/wireless environment, which is not a SOA environment. Interfaces between the SOA based architecture and the mobile phone based services need to be established. Proximity and phone services need to be integrated into the service architecture. Radio and context awareness of service provision needs to be adapted to the radio environment.

The white paper suggests the following **areas of research** in order to let semantic services become the 'glue' for advances mobile service provisioning. Three areas of research have been identified, *(i)* Semantic challenges, *(ii)* Interfaces between semantics and real services and *(iii)* mobile specific adaptation of semantic technologies. In the area of *(i)* semantic challenges research should be focussed on

- Trust, Security (only web based) and Privacy
- user preferences
- scalability
- dynamic ontologies, protected ontologies

In the area of *(ii)* interfaces between semantics and real services we see the need to

- ease mediation of ontologies in order to connect the "swamp of ontologies"
- enhance the usability of tools to create semantic descriptions and ontologies for ordinary developers
- integrate semantic services with existing business engines

- deal with unstructured data, e.g. results from search engines, social tagging
- establish one semantic standard instead of the five now existing ones.

Mobile specific requirements *(iii)* should be taken into account, as the mobile environment

- needs to deal with an “highly varying” radio interface,
- is optimized for speed and low resource consumption, and
- consists of mobile and context specific services, which are not expected to be described as web services.

Despite of the many areas where future research is needed, semantic web services have the potential to be the glue between user requirements, service capabilities and service engines in order to provide personalised and context-aware services.

7. References

[3GPP2003] 3rd Generation Partnership Project, ìStage 2 functional specification of User Equipment (UE) positioning in UTRAN,î 3GPP TS 25.305, Release 5, Sept 2003

[ASG D7.IV, 2006] V. Törmälä et. al., Business analysis, deployment strategy and evaluation of ASG based services, ASG deliverable D7.IV, 2006

[Bruijn05] *Web Service Modeling Ontology (WSMO)*. J. de Bruijn, C. Bussler, J. Domingue, D. Fensel, M. Hepp, M. Kifer, B. Kaenig-Ries, J. Kopecky, R. Lara, E. Oren, A. Polleres, J. Scicluna, M. Stollberg. DERI Technical Report.

[Dorner2006] E. Dorner, J. Kopecky, C. de Saint Marie, M. Stollberg, “Revision of DIP standardisation strategy and results of standardisation efforts”, EU FP6 project DIP, D7.8, Nov 2006

[FOAF2006]FOAF, 2006. http://foaf-project.org/

[Grosof2004b] *SweetRules: Tools for Semantic Web Rules and Ontologies, including Translation, Inferencing, Analysis, and Authoring*. B.N. Grosof, M. Dean, S. Ganjugunte, S. Tabet, C. Neogy, and D. Kolas. http://sweetrules.projects.semwebcentral.org. Software toolkit and documentation. Version 2.0, Dec. 2004.

[Kagal2004] L. Kagal, T. Finin, M. Paolucci, N. Srinivasan, K. Sycara, G. Denker, Authorization and Privacy for Semantic Web Services, IEEE Int. Systems, 2004, vol. 19, no. 4, pp. 50-56

[Kellerer2002] W. Kellerer, M. Wagner, R. Hirschfeld, J. Noll, S. Svaet, J. Ferreira, O. Karasti, T. Hudginson, R. Giaffreda, S. Fallis, J.C. Francis, and C. Fischer, "Systems beyond 3G - Operators' vision", Eurescom Project P1203, December 2002

[Korpipää et al., 2004] P. Korpipää, J. Häkkilä, J. Kela, S. Ronkainen, and I. Känsälä, “Utilising context ontology in mobile device application personalization,” ACM International Conference Proceeding Series; Vol. 83 Proceedings of the 3rd international conference on Mobile and ubiquitous multimedia, ACM Press, 2004, pp. 133-140.

[McIlraith2001] S.A. McIlraith, T. Cao Son, and H. Zeng, Semantic Web Services, IEEE Int. Systems, 2001, vol. 16, no. 2, pp. 46-53

[METEOR-S] METEOR-S: Semantic Web Services and Processes, http://lsdis.cs.uga.edu/projects/meteor-s/

[MWSDI] K. Verma, K. Sivashanmugam, A. Sheth, A. Patil, S. Oundhakar and J. Miller, METEOR-S WSDI: A Scalable Infrastructure of Registries for Semantic Publication and Discovery of Web Services, Journal of Information Technology and Management, Special Issue on Universal Global Integration, Vol. 6, No. 1 (2005) pp. 17-39. Kluwer Academic Publishers.

[Noll2006b] J. Noll, F. Kileng, R. Hinz, D. Roman, M. Pilarski, "Estimating business profitability of Semantic Web Services for Mobile Users", in *S. Schaffert, Y. Sure, Semantic Systems, From Visions to Applications*, Proc. of the Semantics 2006, Österreichische Computer Gesellschaft, pp 195-204

[Noll2006d] J. Noll, "Services and applications in future wireless networks", Telektronikk 3-4.2006, pp 61-71

[Ontobroker] Ontobroker 3.8. Ontoprise, GmbH.

[OWL2006] OWL, 2006. http://www.w3.org/2004/OWL/

[OWL-S] *Web Ontology Language for Web Services,* http://www.daml.org/services/

[OWL-S 1.1] OWL-S: Semantic Markup for Web Services. David Martin, editor. Technical Overview (associated with OWL-S Release 1.1).

[Pfoser et al., 2002] D. Pfoser, E. Pitoura, and N. Tryfona, "Metadata Modeling in a Global Computing Environment," GIS'02, November 8-9, 2002, McLean, Virginia, USA., ACM Press, 2002.

[PSL] Process Specification Language, http://www.mel.nist.gov/psl/

[RDF2006] RDF, 2006. http://www.w3.org/RDF/

[SAWSDL] Semantic Annotation of WSDL, http://www.w3.org/TR/sawsdl/

[SPICE D 3.1, 2006.] Zhdanova, A.V., Boussard, M., Cesar, P., Clavier, E., Gessler, S., Hesselman, C., Kernchen, R., Le Berre, O., Melpignano, D., Nani, R., Patrini, L., Räck, C., Strohbach, M., Sutterer, M., van Kranenburg, H., Villalonga, C., Vitale, A. "Ontology Definition for the DCS and DCS Resource Description, User Rules", EU IST SPICE IP deliverable (D3.1), 2006.

[SVS04] K. Sivashanmugam, K. Verma, A. P. Sheth, Discovery of Web Services in a Federated Registry Environment, Proceedings of IEEE Second International Conference on Web Services, June, 2004, pp. 270-278

[SWSF] Semantic Web Services Framework, http://www.w3.org/Submission/SWSF/

[SWSL] Semantic Web Services Language, http://www.w3.org/Submission/2005/SUBM-SWSF-SWSL-20050909/

[SWSO] Semantic Web Services Ontology, http://www.w3.org/Submission/2005/SUBM-SWSF-SWSO-20050909/

[UK-Tech2006] UK Technology Strategy Board, Information and Communication Technologies, April 2006, http://www.dti.gov.uk/files/file27990.pdf, [accessed 17.12.2006, 23:20]

[Wikipedia, 2007] Semantic Web, from Wikipedia, http://en.wikipedia.org/wiki/Semantic_Web [accessed 15.3.2007]

[WSDL-S] WSDL-S: Adding semantics to WSDL - White paper, http://lsdis.cs.uga.edu/library/download/wsdl-s.pdf

[WSDL 2.0] Web Services Description Language (WSDL) Version 2.0 Part 1: Core Language, R. Chinnici, J-J. Moreau, A. Ryman, S. Weerawarana, Editors. World Wide Web Consortium, 27 March 2006. available at http://www.w3.org/TR/wsdl20.

[WSMO] Web Service Modeling Ontology, http://www.wsmo.org/

[Yang04] FLORA-2 *User's Manual*. G. Yang, M. Kifer, C. Zhao, V. Chowdhary. 2004.