Key Research Challenges for Semantics and the Internet of Services

Introduction

The ServiceWeb 3.0 project has produced two roadmaps focusing on future developments in semantic and service technology and identifying key areas for research. To complement these roadmaps, we provide an additional document which focuses on the open research challenges around some key areas which (i) will play a potentially significant role in business and personal life in the next 5-10 years and (ii) present exciting new challenges for the semantic and service technologies. If these challenges can be resolved by innovative new research, building upon the existing developments in semantic and service technology, in the next years we are hopeful that the semantic and service communities will play an important role in empowering future (1) enterprise service platforms, (2) Linked Services (services over Linked Data), and (3) user-generated services in the mobile context.

Enterprise Services

Overview

An enterprise service may be defined as a set of Web services combined according to some business logic that can be accessed and used when needed to support a particular business process. Currently services are everywhere and almost everything may become a service. We have learned how to abstract from hardware and software and how to virtualize various resources in a form of services and make them available on the Internet (i.e., Internet of Things).

Although there is a critical discussion on SOA due to many failures in industry, there is a consensus that service-orientation is the most promising direction of ICT development. Services, being building blocks of value chains, increase productivity from both business and consumers' perspective. In addition, the rapid development of the Internet in speed, coverage, capabilities and content, enable the further growth of service orientation in various business scenarios. According to Viviane Reding, the European Commissioner for Information Society and Media, there are three main drivers in ICT[1]:

- social networks with shift from "Web 2.0 for fun" to "Web 2.0 for productivity";

- Internet of Things enabling linking information from the virtual world with the physical world through application of open service infrastructures;

- mobile Internet being a new channel for offering and selling products and services.

From an enterprise perspective, the Web may be considered as a global business system within which new values can be created by collaborating or competing enterprises. Undoubtedly, future business will consist of a number of independent and highly specialized partners who cooperate to provide customer-specific solutions. Collaboration networks already play a key role in business as they provide a multitude of advantages, such as e.g.,[1] value chain streamlining, opening up new markets through domain-specific knowledge of

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[1] ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/enet/20090901-fines-position-paper_en.pdf

individual partners, alliance between complementary partners, use of economies of scope and scale.

The recent research findings indicate that new drivers for prosperity and growth for enterprises will come from innovation and using services and resources better by taking advantage of knowledge. Systems of the future will be dominated by interdependent services along with frequent changes of e.g. capacity, availability, legal constraints and ad-hoc business requirements. All of the above issues endorse new challenges towards the Service Web to come. They are discussed within the next section.

State of the Art

Work on enterprise SOA ranges from the classical SOAP-WSDL-UDDI triangle and the plethora of WS-* specifications generated for enterprise needs, which failed to achieve large scale uptake due to their complexity and associated cost, to lightweight approaches around REST and XML which typically fail to meet the needs of complex, possibly critical business processes. Similarly in the case of semantic service specification, there has been a move away from more complex and hence difficult to learn and adopt specifications like OWL-S and WSMO and towards lightweight means to add a simpler layer of semantic annotation to service descriptions (WSMO-Lite, MicroWSMO, SAWSDL) which could bring greater benefits in service discovery, mediation, composition and execution.
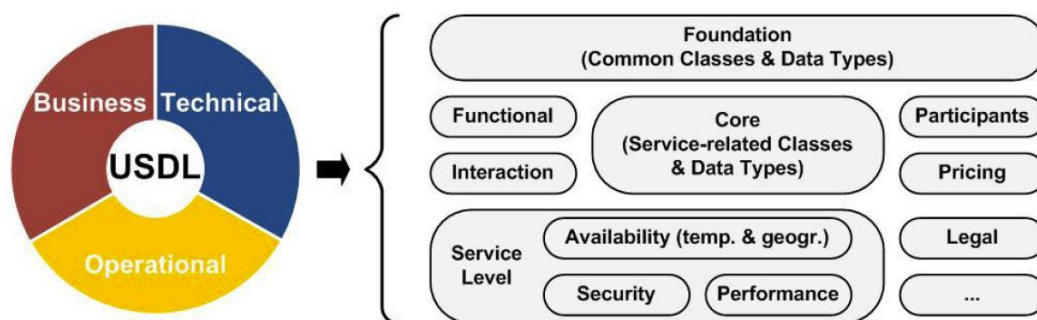
Just recently, a new service description language USDL has been promoted by one of the largest software providers in the world, SAP – see http://www.internet-of-services.com/

What is particularly interesting about USDL is that "the most significant proposals to describe services that have influenced USDL include WSDL, WSMO, and OWL-S"[2]. With the weight of a major industry player behind it, it will be interesting to see how USDL develops in the near future.

Research Challenges

Challenge 1: Open service delivery platform

The evolution of service orientation goes towards creation of semantically enabled open marketplaces supporting the concept of dynamic processes and offering services for enterprises, communities, public bodies, citizens and consumers. Idea of service markets, e.g., dynamic business networks [2], Web services ecosystems [3], IT service parks [4] or B2B e-marketplaces [5] and Global Service Delivery Platform [6], although strong on the research side, is currently still under its way when it comes to its implementation.

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[2] http://www.internet-of-services.com/uploads/media/USDL-Information-Sheet.pdf

One of the most comprehensive initiatives, when it comes to the creation of such platforms, is the Service Delivery Framework (SDF)[3] that is to facilitate provisioning and delivery of services beyond "firewalls", out to global business networks. SDF is to offer the support for service discovery, re-design, optimization on a global scale, e.g. for: "exposure beyond software registries to service marketplaces; new service innovations and channels through third-parties potentially unknown to original providers; re-hosting through low-cost cloud environments for SMEs and untapped consumer segments, outsourcing interoperability and other service delivery support functions through specialists like gateways and integrators – among various provisioning considerations"[4]. Although quite promising, it is still in its conceptual stage.

Thus, the development of a new consolidated and open infrastructure that would globally coordinate the creation, deployment and execution of applications and offer an initial fixed set of services, in order to enable enterprises to build their business infrastructure easily at low or even no cost, and fully integrate that infrastructure into the wider paradigms of business, still remains a challenge. It is not yet clear whether we should aim at creation of one global platform or should there be a proliferation of such artefacts. However, the current research ideas indicate that the connected system of interoperable platforms may be the solution here.

Open questions: What should be the business model followed by the platform? Who should be its owner? What functionalities should it offer? How a service/resource should be described and managed on the platform? Which services should constitute the initial fixed set offered by a platform? How may it facilitate reaching down to the physical layer and provide support for offering capabilities of resources (e.g., smart items) as services or mash-ups thus, allowing things to become active participants of processes? As such platforms should be targeted also as SMEs, thus another question arises, namely how to abstract the complexity associated with the platform's functionality and open it to the millions of European SMEs, who do not have dedicated IT employees and cannot afford new technology investments?

Challenge 2: Generic description allowing creating abstraction over services and resources

A comprehensive, yet generic, description language for services and things constitutes a fundamental element in the framework of service networks. The key element of the description should be both technology as well as business oriented characteristics of an artefact (i.e. a service or resource). Currently used service description languages (either syntactic or semantic ones) are not sufficient to support all requirements of service networks and thus, need to be supplemented with a language allowing to describe business, functional and technical characteristics of both service and resources in an unambiguous manner. One of the promising propositions aiming at this aim, but still not mature enough, is USDL[5] (Unified Service Description Language) used for describing business and technical services and creating a unified description of related research efforts.

In addition, the appearance of a high number of competing items requires more complex approach to the issue of quality of service and its result. The main challenge is connected with the creation of relevant quality models that could be used in automated interactions as well as development of methods and tools that would allow for automated assessment (independently of providers) of quality of results delivered.

Open questions: How to represent and automatically assess the quality of services and resources? What quality models should be used to describe business items? How to link the quality models with the pricing model? How to link the quality of an individual item and the quality of the entire assembled process? What is the relation between technical and business

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[3] http://www.internet-of-services.com/

[4] http://www.internet-of-services.com/index.php?id=25

[5] http://www.internet-of-services.com/index.php?id=24

quality of an artefact? How to represent a technical, business and functional characteristic of a service and a thing in a generic, yet comprehensive manner?

Challenge 3: Support for new business model and pricing

Following [7], traditional concepts of providers and customers, servers and clients, computational farms, data/content/information centres and administrative domains will dramatically change with the evolution of Future Internet. The virtualization of resources using cloud-computing paradigm, dynamic composition of services, participation of end-users in the process of content creation and distribution (prosumers), are examples of new features that will characterize the new era and impose that successful business models of the future will be different from those of today.

In addition, the idea of dynamic processes supported by the Future Internet where different services may be used during execution depending on the current state of the environment as well requirements of a specific actor, impacts the pricing and billing strategies that should be utilised by providers and vendors. In contrast to previous situations, consumers are not attached to any specific provider and the variety of services offering similar functionality allows for flexible and dynamic selection of services to be used. It will cause unpredictability of the level of service consumption as well as would make some of the pricing models obsolete.

Open questions: How the active participation of end-users in the creation and distribution of digital goods affects the currently followed business models and what changes should be introduced in order to support it? What should be the business model and pricing strategy to support usage of spare (computational) capacities offered to the traditional (computing) resource owners, helping them to deal with unexpected peaks in demand? What tools should be introduced to support this kind of exchange? How business models can capture and support the dynamic nature of the emerging and changing agreements? What actions are needed to facilitate the exchange of user-generated content/services (whether for payment or not)? How can the origin of user-generated content/services be verified? How can small payments be made securely and cheaply?

Challenge 4: Service management and partner collaboration models including intellectual rights management

Future processes carried out with support of service delivery platforms may become quite complex, unobservable and almost impossible to monitor and thus, extremely difficult to manage. Various network structures of collaborating partners are to be developed that require definition of different cooperation models. The collaboration models need to support management of the created networks, define responsibilities of each party as well as terms of collaboration and data access policy. The emergence of new markets and services as well as new ways of their applications, requires defining new approaches to ownership (e.g. in case of composite services). In addition, an appropriate tool support needs to be offered.

Open questions: Which service management models (e.g., centralized, distributed, federated) should be followed? How the information integrity and non-repudiation can be ensured? How the organizational as well as legal requirements can be met? How to effectively manage collaboration between many parties? What kind of cooperation models should be followed when it comes to the responsibilities of each party, terms of collaboration and data access policy? What features should a tool supporting the service management and new collaboration model have? Who is the owner of the system combined out of services (who benefits from the added value also in case when there are open source elements used)? Will the new EC licensing scheme EUPL facilitate the development of services for reuse?

Challenge 5: Flexible and agile business processes

Business process modelling aims at providing description of a company by means of its business processes that are realized also in cooperation with external parties. However, the level of cooperation envisioned by today's modelling notations is quite limited and the issue of the interoperability neglected. Therefore, it is difficult to use them for capturing flexible and agile business processes (BP).

The BP in the next few years will become interactive, and the business flow will vary depending on the availability, behaviour and requirements of actors, services or resources. Companies that want to react quickly to changing market conditions will focus on development of highly modular processes, enabling quick reconfiguration and adaptation for the needs of the execution. These modules most probably will come from different providers, therefore ensuring interoperability is also crucial.

Open questions: how to provide a model of a highly modular process including a number of market participants? Is it possible to capture this change by proposing extensions to the most popular modelling notations? How to smoothly transform the business process model to its executable representation? How to support changeability and versioning of processes? How to represent a business process model that is highly customizable and reactive to changes? How to implement and manage such process in an automated manner? How to represent in a formal manner rules and information needs of a process as well as influence of the acquired information on its execution path?

Challenge 6: Personalized and reliable dynamic service composition

In the future, processes in value networks are expected to be arranged in real-time using dynamic service composition and other new mechanisms, on a scale exceeding current practices. In addition, a vast amount of items with their own identities, physical attributes, virtual personalities and intelligent interfaces, are expected to become active participants in business processes. This raises additional challenges aiming at development of reliable and efficient dynamic service composition mechanisms.

Open questions: How to describe artefacts to enable reliable dynamic service composition? How to conduct accurate and reliable real-time service composition taking into account a plethora of competing services and resources with different characteristics and interfaces? How to do it efficiently? How to make sure that the resulting process is in accordance with the business requirements and expectations of clients?

Challenge 7: Trust, security and distributed information management

Arranging processes in real-time using dynamic service composition changes the way that organizations manage information, as done by e.g., cloud computing and mobile access to information. In addition, new types of information appear (e.g. produced by mobile and/or sensor devices and actuators) that need to be managed within the business process accordingly. In addition, complex and distributed business processes involving a number of parties require creating trusted environments for collaboration. The automated interactions as well as personalization of delivered content and services, would also require development of identity tracking and management mechanisms as well as appropriate facilities to store the private data.

Open questions: How to deal with varying information structures that are used across the complex transaction chains? How to carry out the automated data collection and identity tracking such as to allow for provision of highly personalized content but at the same time do not pose a privacy threat? What features service platforms should have in order to constitute trusted environment for collaborating partners?

Challenge 8: Standardisation and interoperability

The application of services from different vendors as well as selling services to diverse customers demands ensuring their interoperability. Interoperability is an ability of two or more services, networks, devices, etc. to exchange information and use it. The interoperability

is usually guaranteed via application of standards which establish engineering or technical criteria, methods, processes, etc. The adoption of standards should be widespread to enable fulfilment of the Future Internet vision. The process of defining and adopting standards should be encouraged and promoted by all stakeholders, taking into account new requirements for interoperability. This issue is also closely related to service platforms that are to provide mechanisms i.e. for service selection, composition and enactment.

Open questions: What standards are needed, in particular metadata standards, to ensure searchability and interoperability? What kind of incentives should be offered to ensure application of interoperable standards?

Linked Services: Services Over Linked Data

Overview

Over the last few years, a significant portion of research has been devoted to creating what is referred to as the Web of Linked Data or Semantic Web – "a Web of things in the world, described by data on the Web"[6]. This research has also recently gained a high profile on the policy level, with the UK government recently announcing, in a prime ministerial speech, the setting up of an Institute of Web Science, as part of its initiative to build a future Digital Britain. The institute will be headed by Sir Tim Berners-Lee, inventor of the Web, and Professor Nigel Shadbolt, who is, along with Sir Tim, one of the leading advocates of the Web of Data or Semantic Web. In the words of the British Prime Minister, "Underpinning the digital transformation that we are likely to see over the coming decade is the creation of the next generation of the web - what is called the *semantic web*, or the web of linked data". [7]

Analogous to the *Linked Data* term[8], this approach was recently dubbed as the *Linked Service* approach[9]. Due to the fact that such service annotations are much easier to produce and can be populated with references to widely established Linked Data vocabularies, they address a much wider audience and allow even non-SWS experts and lay people to describe and annotate services. A Linked Services approach can improve on the applications being constructed, for example, within the UK Open Data initiative.

State of the Art

The Web of Data is based upon a set of linked data principles, which include:

- Using URIs to name things;
- Using HTTP URIs so that people can lookup these names;
- Providing useful information in these URIs using standards like RDF and SPARQL,
- Including links to other URIs so that additional information can be discovered.

Since these principles were outlined in 2006, there has been a large uptake most notably and also others that have produced a vast amount of data concerning reviews, scientific information, geographical information and more recently governmental data, to name a few.

Currently substantial efforts are underway trying to exploit this growing Web of Data. Although a number of useful applications have been developed already, they hardly go beyond presenting data gathered from different sources. Thus, to date the great potential of

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[6] Bizer, C., T. Heath, et al. (2009). "Linked data - The Story So Far." Special Issue on Linked data, International Journal on Semantic Web and Information Systems (IJSWIS).

[7] http://www.youtube.com/user/downingst?blend=5&ob=4#p/u/0/0tNkRkPPmOE

[8] Bizer, C., T. Heath, et al. (2009). "Linked data - The Story So Far." Special Issue on Linked data, International Journal on Semantic Web and Information Systems (IJSWIS).

[9] Pedrinaci, C., Domingue, J., and Reto Krummenacher (2010) Services and the Web of Data: An Unexploited Symbiosis, Workshop: Linked AI: AAAI Spring Symposium "Linked data Meets Artificial Intelligence".

this massive data space remains unexploited. The main challenge that the Web of Data is now confronted with is the need to identify means by which systems that carry out advanced processing over the data can systematically be developed in a convenient way. Service-oriented computing has been argued to be a suitable approach to supporting the construction of advanced applications that can exploit this data[10].

Along these lines, the EU-funded project SOA4ALL, one of the projects to which Service Web 3.0 made strategic collaborations, has developed a novel and open platform for publishing semantic annotations of services based on a direct application of linked data principles. This platform, called iServe, supports publishing service annotations as linked data—which we refer to as Linked Services—expressed in terms of a simple conceptual model that is suitable for both human and machine consumption and abstracts away the existing heterogeneity around service kinds and annotation formalisms. In particular iServe:

- Supports importing service annotations in a range of formalisms (e.g., SAWSDL, WSMO-Lite, MicroWSMO) that cover both WSDL services and Web APIs;
- Provides means for publishing semantic annotations of services which are automatically assigned a resolvable HTTP URI;
- Includes support for content negotiation so that service annotations can be returned in plain HTML or in RDF for direct machine consumption;
- Provides a SPARQL endpoint allowing advanced querying over the services annotations;
- Offers a read/write REST API so that services can easily be retrieved and published from remote applications; and
- Automatically generates links between the published service annotations and additional documents on the Web such as the original service description or documentation so that users and machines can easily discover more information.

We view that developing SWS based applications on top of Linked Data has the following benefits. From a Linked Data viewpoint web applications which use Linked Data gain increased transparency, provenance and re-usability since the underlying components are visible and described in a machine processable way. From a software engineering perspective the service abstraction supports the development of complex applications in a distributed manner. From a services perspective Linked Data simplifies SWS creation providing ready-made domain vocabularies, background knowledge and input data in semantic form.

Another important development that has implications for Linked Services on the Web is the release of "Open Graph" by Facebook. Open Graph extends Facebook's "like" feature to external web sites, allowing users to feed their activity back into their Facebook news feeds. With this feature, Facebook has made a huge move in driving forward the semantic Web[11].

Research Challenges

Thus, in order to enable Linked Services to flourish the following challenges need to be met and principles need to be adopted:

1. **Web Applications are service oriented.** As mentioned above web applications gain transparency, increased provenance and reusability if built in a service oriented fashion. Moreover, compositions or mashups should be defined in terms of existing published services and should themselves be published as services defined in a form that can be directly processed and published as linked data. The actual compositions will provide highly valuable links between services showing those that are closely related or composable, therefore allowing developers to discover interesting services while browsing others driven by existing compositions.

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[10] Pedrinaci, C., Domingue, J., and Reto Krummenacher (2010) Services and the Web of Data: An Unexploited Symbiosis, Workshop: Linked AI: AAAI Spring Symposium "Linked data Meets Artificial Intelligence".

[11] http://www.zdnet.com/blog/feeds/has-facebook-won-the-web-war-against-google/2681

2. **Services for the Web rather than Web services**. Semantic Web services should better support the use of services on the Web and should therefore be driven by current approaches on the Web. For instance, semantic Web services have mostly focused on Web services whereas current trends on the Web show that Web APIs and RESTful services are very popular. Any approach to semantic Web services description should therefore embrace both traditional Web services and Web APIs and the annotation mechanisms should enrich existing standards and support current practices: not everyone follows REST principles and developers tend to prefer HTML descriptions to WADL files.

3. **Publish services as Linked Data**. *Service descriptions are a particular kind of highly valuable data: data that informs us about existing reusable functionality exposed somewhere on the Web that processes and/or generates data*. Services should therefore be published as linked data so that applications can easily discover and process their descriptions. Doing so means essentially that: i) each service and the elements it is composed of (e.g., lifting and lowering mechanisms) should be given a resolvable HTTP URI; ii) they should be published using standards like RDF and SPARQL and iii) links should be created to related information:
   a. Services should be linked to their syntactic definitions with *rdfs:definedBy* relations. This information can help track the endpoint, similar services, and most importantly it can support their actual invocation.
   b. Services should be linked to the same service published by other Web sites with *owl: sameAs* relations.
   c. Services should be linked to additional information about them (e.g., documentation) by means of *rdfs: seeAlso* relations.

4. **Ease of Use**. Tools provided should be easy-to-use and only require minimal changes to existing working practices and currently used environments. Support should be provided to minimize labour-intensive tasks. Finally, SWS should be easy to invoke – comparable with the effort required to invoke the corresponding web application.

5. **Standards-based**. In order to provide maximal compatibility it is necessary to build upon existing Web standards notably SAWSDL but also RDF(S), OWL and SPARQL as promoted by Linked Data principles. The next principle will cater for the inclusion of specific extensions (e.g., rule languages) on a case-by-case basis.

6. **Extensibility**. Closely related to the previous principle is the need to seamlessly support the inclusion of additional extensions. Modular extensions should be backwards compatible with existing systems and cater for the inclusion of application-specific extensions as the need arises.

7. **Enable Integration with Web 2.0 and Social Network Technologies**. In the same manner that the growth of REST services is based upon their use within Web 2.0 and social network applications we believe that this holds the most promising path for the growth of services on the Web. This is exemplified by Facebook's recent steps in the direction of the Semantic Web with the release of Open Graph. However, one of the challenges that this represents is that while Open Graph is a step forward, users cannot forget the privacy implications of this type of feature. Privacy still remains the unknown black hole of the Semantic Web, and the ability for brands to make Facebook integration even easier will create an explosion of Facebook inclusion on web sites. This could lead many users even further down the path of allowing themselves to be potentially profiled.[12]

Linked services are thus web applications composed of services where the semantic descriptions are available as Linked Data. In order to publish services on the Web of Data it is necessary to provide a common vocabulary based on existing Web standards able to describe

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[12] http://www.zdnet.com/blog/feeds/has-facebook-won-the-web-war-against-google/2681

services in a way that allows machines to automatically locate and filter services according to their functionality or the data they handle, and to appropriately support their automatic invocation. To this end, we have devised WSMO-Lite[13], a minimal extension to SAWSDL, MicroWSMO a microformat-like language for annotating Web APIs, and the Minimal Service Model a simple RDF(S) model able to capture the semantics for both Web services and Web APIs in a common model that can easily be published in the Web of Data. The use of RDF(S) is based on principles 2, 3 and 5 above.

Summary

There are a number of ways in which RDF data can be used within a Linked Data context and also a number of ways in which semantic data can support service descriptions. Links from service descriptions to other linked data sets would be based primarily on descriptions of the types of data which form the inputs and output of a service. As the number of service descriptions grow we would expect that the services descriptions themselves become linked expressing relations including: equivalent-functionality, super-functionality and sub-functionality. Secondly (4b), we can create service descriptions for applications which directly use RDF data following principle 1. We see now that communities are forming around linked data sets with the common goal of creating useful applications on top of the data. One of the most well known of these is the UK Open Government Data initiative[14] where over 1100 data sets have been released and now there is a focus on building RDF based 'Apps'. The trend is towards a new approach to SWS which begins from semantic data rather than from standard Web services.

User Generated Services in the Mobile Context

Overview

The market for mobile services will expand significantly in the next years. The explosion in usage of smartphones and the application store model to sell individual services to consumers opens a new and attractive market for developers of simple, useful location-based applications. The potential of this market can be seen in the growth of mobile application stores, led by the iPhone app store which reported (Nov 4, 2009) 100,000 applications and over 2 billion downloads since launch. In these settings, considering basic human preferences for content access and media consumption on-the-go and an ever-improving access to mobile Internet, access to useful services 'on the move' will become a dominant social trend and the subject of new business models in the next few years.

Today the provision of services in the mobile context is handled by professional developers working with specific APIs and development environments for iPhone, Android, Symbian, Windows Mobile etc. While the number of mobile applications is already significant, users are unable to model their own applications to meet their own personal needs, and hence existing applications number far less than the number of users and devices (each arguably unique in their needs and requirements).

Provided that the actual action of creating a service for a particular need or situation is eased for the 'average' mobile user, e.g. modeled as the composition of a set of existing services combined with filling in values into a list of parameters, we can expect User Generated

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[13] Vitvar, T., Kopecky, J., Viskova, J., Fensel, D. WSMO-Lite Annotations for Web Services. Proceedings of the 5th European Semantic Web Conference (2008)
[14] http://data.hmg.gov.uk

Services (UGS) to be the next big paradigm shift in mobile computing, just as the so-called Web 2.0 transformed the experience of the World Wide Web for individual surfers (allowing them to create an uniquely personalized Web meeting their requirements and situation, as opposed to a static Web which is the same for each person).

Web services offer a useful abstraction from the different and incompatible development environments, and semantics can provide the necessary machine understanding and automated mediation between data formats and processes. We expect the combination of Web services and semantics to enable the future User Generated Service platforms for mobile computing.

State of the Art

Semantic, machine processable and easy to share service descriptions are also the direction for **mobile services**, but the technologies developed for the Web are computationally too heavy for mobile services. Moreover, as OWL-S or WSMO specifications are poorly extensible and often difficult to understand and implement for humans (hence their current slow adoption pace), semantic mobile services will employ a generally lighter, simpler service specification which can be extended on the user's demand. Another important aspect for mobile services that Web service modelling technology overlooks is the implementation of the mobile service *ubiquity* vision, i.e., the ability to run services any time at any place in a context-aware fashion (e.g. the "right" modality and at the "right" device). In the social, community-driven usage of mobile services vs. web services, the typical attention deficit of mobile device users should be taken into account, which would require usage of different service search, delivery, presentation and sharing techniques.

The role of Web-based services in the mobile application space can be illustrated by the Siri application, which takes the form of a sort of "personal assistant". As shown in the below graphic, which is a shot of one slide presenting the Siri application, the back-end data for the application is sourced from multiple Web services and APIs, which are combined by the application with the help of domain and task models (think: ontologies!) and present as a result "intelligence" at the user interface level. Hence, Siri is representing a new generation of mobile application which is more of an intelligent (= semantic), service platform (= automatic composition of individual services from the Web), rather than one of today's standalone and static downloadable applications.

User-generated microservices are active content components or lightweight applications which allow users to obtain and provide information, e.g. opinions, recommendation, location or speed, and functionality to fellow users. They can be created and consumed on the end-user's own terminals or "on-the-go"7. Such content and applications have been shown to be highly desirable for the end-user on mobile platforms, e.g. for location based services addressing virtual communities and entertainment 9.

A primary example of this are *augmented reality* applications. Location-based services and augmented reality are seen as potential killer applications of the mobile Internet because users are enabled to access additional information related to where they are, what they are seeing, or what they are doing, as well as instantly purchase related services and content. The first mobile augmented reality applications are entering this market (Layar, Wikitude). Consumer AR success will need better image recognition, cooperation between data providers, more granular and optimized meta-information such as geo-location and the means to integrate additional content in the Augmented Reality browser ("Mobile Augmented Reality Today and Tomorrow", John du Pre Gauntt, GigaOM Pro[15]) – all areas which could be supported by semantic and service technology.

Importantly, these applications provide only the underlying technology for augmented reality. Others can develop their own augmented content layers over the augmented reality browser. For example, Layar reported in February 2010 that it had 375 active layers and 1200 layers in development. Developers only need to concentrate on the content, and don't need to worry about "mass market distribution, developing for multiple mobile platforms, or financial administration"[16]. While basic development skills are a pre-requisite, Layar developers have also created several tools to ease the layer development process[17].

We see here a movement towards letting people develop their own mobile applications on top of existing sets of services which handle all of the generic aspects, such as providing the phone's GPS information, handling mobile billing or enabling in-application access to Web-based content and services. Currently, this is still the reserve of trained programmers.

Research Challenges

Unlike the Social Semantic Web 10, many aspects of semantic user-generated microservices are yet to be explored. From the front-end perspective, development environments need to be provided which are accessible and intuitive to non-expert service creators. From the back-end perspective, service platforms need to be integrated with the mobile environment.

Front end challenges

In the recent years, a **web mashup ecosystem** has evolved, which leverages open APIs to offer new, innovative applications[18]. Current examples for end-user created software on the Web such as Microsoft Popfly or Yahoo! Pipes also allow end users to create new applications by visual editing of functional blocks. However, even visual editing still requires significant (programming) knowledge from users. With respect to the mobile domain, current software creation approaches (e.g.7) are at a very early stage and are not tailored to mobile

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[15] http://pro.gigaom.com/2010/01/report-mobile-augmented-reality-today-and-tomorrow/ published January 2010

[16] http://www.readwriteweb.com/start/2010/02/layar-app-store-ar.php

[17] http://site.layar.com/create/tools/

[18] http://www.programmableweb.com/matrix

devices and usage scenarios (with regard to user interfaces and context information) as well as community usage.

The research area of **End-User Development** (cf.7) considers alternative approaches to allow end users to create software (e.g. Programming by Example). However, these directions will need to be explored in the context of open, scientific communities and mobile usage patterns. In addition, current end-user development methods are still at an early stage and can benefit from semantic technologies to better describe the behavior of functional blocks and to offer semi-automated software composition.

For example, the mCuidad project has identified the following key requirements as crucial enablers for user-provided services [12]:

- There needs to be easy, direct access to terminal capabilities and other information sources, so that users will be able to use them in their services

- New paradigms for service creation need to be envisioned, so as to allow impulsive service creation from mobile terminals

- The impulsiveness that drives user-provided services requires novel strategies for context-based search so that only the most relevant mobile services are shown.

Back end challenges

Current service platforms such as the foreseen Global Service Delivery Platform (GSDP) which shall underlie the Future Internet of Services, NEXOF-RA the reference architecture for services emerging from a wide research and industry collaboration, or enterprise service platforms being developed such as from COIN, do not explicitly address the issues of creation, composition and consumption of user-generated services in the mobile context.

Context-aware and personalisation issues will be crucial when looking for micro services in a future in mobility [13]:
- Ecosystem made up of millions of providers will offer microservices on the go.
- Users' context will be shifting as they move, as well as users' necessities and preferences.
- Past history of the user is an important component of the context, it conforms the user life flow.
- Microservices have also context, useful to know their popularity, HW & SW dependencies, usage history, etc.

Summary

User-generated services in the mobile context will increase in significance and popularity in the next years. Adaptable service platforms for the creation, composition and consumption of user-generated services should be produced with semantics in the back-end to support the appropriate description, mediation and automation of services. For this, both the back-end issues of context and personalization in the mobile domain and the front-end issues of service mash-ups and end-user development for non-expert mobile users need to be addressed.

Conclusions

This document has introduced three key trends in semantics and services with a strong potential for a wide uptake in the near future, with subsequent impact in business activities, as well as personal life. However, the semantic and service technologies represented by our

vision of the Service Web need still to develop and adapt to meet the new requirements for (i) enterprise services, (ii) services over Linked Data, and (iii) user-generated services in the mobile context. We have illustrated some research challenges in that regard which we hope can be taken up by semantic and service researchers in the next years, in order to ensure the wider success of the Service Web.

References

1. Reding, V., "Internet of the future: Europe must be a key player"; Speech; Future of the Internet initiative of the Lisbon Council, Brussels, 2 February 2009, http://www.future-internet.eu/fileadmin/documents/speeches/reding_future_of_the_internet.pdf

2. Bichler, M.iK.J. Lin, Service oriented computing. Computer, 2006. 39(3): p. 99-101.

3. Barros, A., M. Dumas, iP. Bruza, The move to Web services ecosystem. BPTrends, 2005.

4. Petrie, C.iC. Bussler, The Myth of Open Web Services. The Rise of the Service Parks. IEEE Internet Computing, 2008. 12(3): p. 94-96.

5. Abramowicz, W., i inni, E-Marketplace for Semantic Web Services, in Service-Oriented Computing - ICSOC 2008, 6th International Conference, Sydney, Australia, December 1-5, 2008. 2008, Springer Berlin/Heidelberg. p. 271-285.

6. Krummenacher R., Domingue, J., Pedrinaci, C., Simperl E., SOA4All: Towards a Global Service Delivery Platform, in: Towards the Future Internet - Emerging Trends from European Research, Eds. Georgios Tselentis, Alex Galis, Anastasius Gavras, Srdjan Krco, Volkmar Lotz, Elena Simperl, Burkhard Stiller, Theodore Zahariadis, IOS Press, 2010

7. Future Internet Assembly, What will the Future Internet deliver for Enterprises?, http://services.future-internet.eu/index.php/Enterprises

8. Shin, Y., Yu, C., Chung, S., Kim, S.: End-User Driven Service Creation for Converged Service of Telecom and Internet. Fourth Advanced International Conference on Telecommunications (AICT) (June 2008) 71 – 76

9. Henry Lieberman , Fabio Paternò , Volker Wulf, End User Development (Human-Computer Interaction Series), Springer-Verlag New York, Inc., Secaucus, NJ, 2006

10. E. Kaasinen: "User needs for location-aware mobile services". Int. J. of Personal and Ubiquitous Computing 7(1): 70-79, Springer London, 2003.

11. S. Auer, C. Bizer, C. Müller, A.V. Zhdanova (eds.): "The Social Semantic Web", Bonner Köllen Verlag, Lecture Notes in Informatics (LNI), Vol. 113, September 2007

12. D. Urdiales, R. de las Heras, M. Narganes, M. Davies, A. Zhdanova, B. Christophe, L. Maknavicius, M. Immonen, J. Heinilä, P. Barnaghi: m:Cuidad – unleashing mobile user-provided services. In proceedings of the Mobile Widgets

Workshop, co-organised with the 18th International World Wide Web Conference (WWW2009), Madrid, Spain, 2009.

13.   Belén Martinez, Maria González and Artzai Picón: User-created services in a context aware mobile platform. In the 1st Workshop: Putting Mobile Service into Context, ICT 2009, Santander, Spain, 2009.