Enabling Smart Data Services for Behavioural Change

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Abstract

A vast amount of real world physical infrastructures comprising converged media, mobile, sensor-empowered environments, and social, context-based and information Internet services are being addressed with the use of Smart Data service enablers for interoperation and human participation and behavior change. I demonstrate such approach in general and for selected application domains going beyond the current state of the art of ontology-based service interfacing, integration and user involvement. Most results have been evaluated within real industrial products, with real life data and services, as well as with real end users.

1 Introduction

The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation." - this statement of Tim Berners-Lee [Ber01] has gained even more relevance since the start of this century.

Technology changes the ways in which people communicate and behave. Enabling new processes and services based on regularly emerging technological solutions and systems is not trivial. Yet, services remain crucial. As estimated by the IBM-driven Service Science initiative[1], global markets are increasingly service-based economies, where in developed countries up to 80% of the economy is service-based [Mag08]. Thus, the employment growth will be further concentrated in the service-providing sectors of the global economy. While a service is defined as the application of competences for the benefit of another [Var04] and is considered to be an intangible economic good, this work generally applies to such services only involved in information technology within the realm of computer science.

Success in services-oriented research and industrial settings depends, to a large extent, on the ability to identify promising directions and technologies, and to take up those which eventually lead to economically viable services or products. Rapid design and development of new services is, however, hampered due to the fact that a large number of infrastructures and industries (for example, those based on the telecommunication networks and developments in the Internet of the Things) are locked behind the so-called "walled gardens", which impose difficulties in the sharing of the information and meaning necessary for seamless behavioral change of the users. The growing importance of these infrastructures and industries can no longer be underestimated.

From a societal perspective, the current, soaring human population of Earth leads to such factors as (i) the boom of the communication infrastructures (e.g. the number of mobile phone devices has already exceeded the number of

[1] "Making Service Science Mainstream", a white paper based on the 2009 Service Science Summit. URL: http://www.servicefactory.aalto.fi/fi/wp-content/themes/default/Service_Science_Summit_White_Paper.pdf.

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people), (ii) new types of communication and social inclusion patterns (e.g. social media, sharing economy), as well as eventually (iii) depleting natural energy resources. These are substantial examples of factors that need to be addressed in order to make interoperable technology in networked systems, which in turn provide semantic data intelligence for intervention services enabling behavioral change.

Further global and local challenges experienced by the rapidly developing humanity include global warming/climate change, dis-balances in demand and supply, among many others. Mastering most (if not all) of them require a behavior change. Behavioral change is difficult to achieve per se, and it is important that technology – as a major enabler - has a positive rather than a negative impact here.

Finally, the dramatic growth of data volumes (Big Data, Internet of Things) and the data's increased power and impact and on the people's daily lives are calling for new types, practices and policies of behavior with data. Also, a move from Big Data to Smart Data has been clearly observable lately, in order to have the data usable in intelligent real-world applications[2].

These factors made the role of semantic technology even more crucial: in terms of providing a well-defined meaning, and eventually delivering Smart Data for a functional and fair data value chain.

This paper is structured as follows. A general approach to the addressed challenge is presented in Section 2. Specific examples are provided in Section 3. Section 4 concludes the paper.

2 General Approach

The conducted research has the following high level objective:

- to design and develop the technology and prosumer engagement prerequisites necessary for the ***enabling of semantically enriched services in heterogeneous networked systems and their uptake by the masses***, for the sake of mutual benefit of the participators.

On a more detailed level, the conducted research has the following technological objectives:

- Deriving new models and interfaces, techniques, approaches for participatory services representation in networked systems,
- Enabling prosumers to benefit from data, knowledge and services reuse,
- Enabling participators to create added value new and converged services (also, reusing the existing data, knowledge and services – see the previous bullet), and
- Provisioning of intervention mechanisms for effective engagement of the users in employing the new types of services e.g. commercially re-applying them across platforms.

From these technologically detailed questions, a need to 'understand' and interlink content and other objects follows, stemming from the numerous heterogeneous sources. This need is specifically addressed by applying semantic technologies to a variety of networked systems, also separately from the Web.

Particularly, the designed platforms and services comprise usage of data, and from this, a lower-level and more technical perspective, the **research sub-questions** comprise the following:

1) Service and Information Representation Layer: Converting large volumes of raw data to smaller volumes of 'processed' data:
   - Streaming, new data acquisition infrastructures,
   - Data modeling, mining, analysis, processing, distribution,
   - Complex event processing (e.g. in-house behavior identification).
2) Knowledge Acquisition and Integration Layer: Employing data which is neither 'free' nor 'open':
   - How to acquire information from prosumers and systems, store, discover and link it,
   - How to collect, discover and valorise it,
   - How to define and communicate its quality / provenance, and
   - How to keep it up-to-date, as ontologies and knowledge evolve over time.
3) Social Processes and Prosumer Engagement Layer: Establishment of radically new B2B and B2C services based on the above, and investigating their deployment successes in terms of their applied usefulness and the potential of user involvement. Obviously, the networked systems provide multitude opportunities to connect objects (e.g. now it is possible to place a carton of milk on the Internet, etc.), but the exact participatory services designs, and particularly, their technological and functional viability, need to be systematically approached. The objective is

[2] "From Big to Smart Data: Dossier", Siemens (2014): https://www.siemens.com/innovation/en/home/pictures-of-the-future/digitalization-and-software/from-big-data-to-smart-data-dossier.html

to get the stakeholders to use the new kind of services, with which they are not familiar, and create a win-win scenario marketplace.

These research sub-questions sum up the **overall research question** regarding the design and implementation of enabling efficient participation with services over semantically interlinked heterogeneous networked systems. The approach here relies, in particular, on the semantic knowledge modeling layer and ontology-based techniques.

In order to enable networked semantic services to be taken up by the masses in the critical and high impact sectors, certain *existing technologies* are needed to be applied and adapted. Figure 1 illustrates the cornerstone components of the proposed solution, resulting in the enablement of the intervention networked services. The parts, which become newly connected into a networked participatory service infrastructure, are colored in green – and hence the design, implementation and assessment of such infrastructure form the contribution of the work. The unified approach goes beyond the typical knowledge engineering and Semantic Web solutions, as we know them. The parts, which are left in blue, are easier to interlink and combine, compared to the parts colored in green.

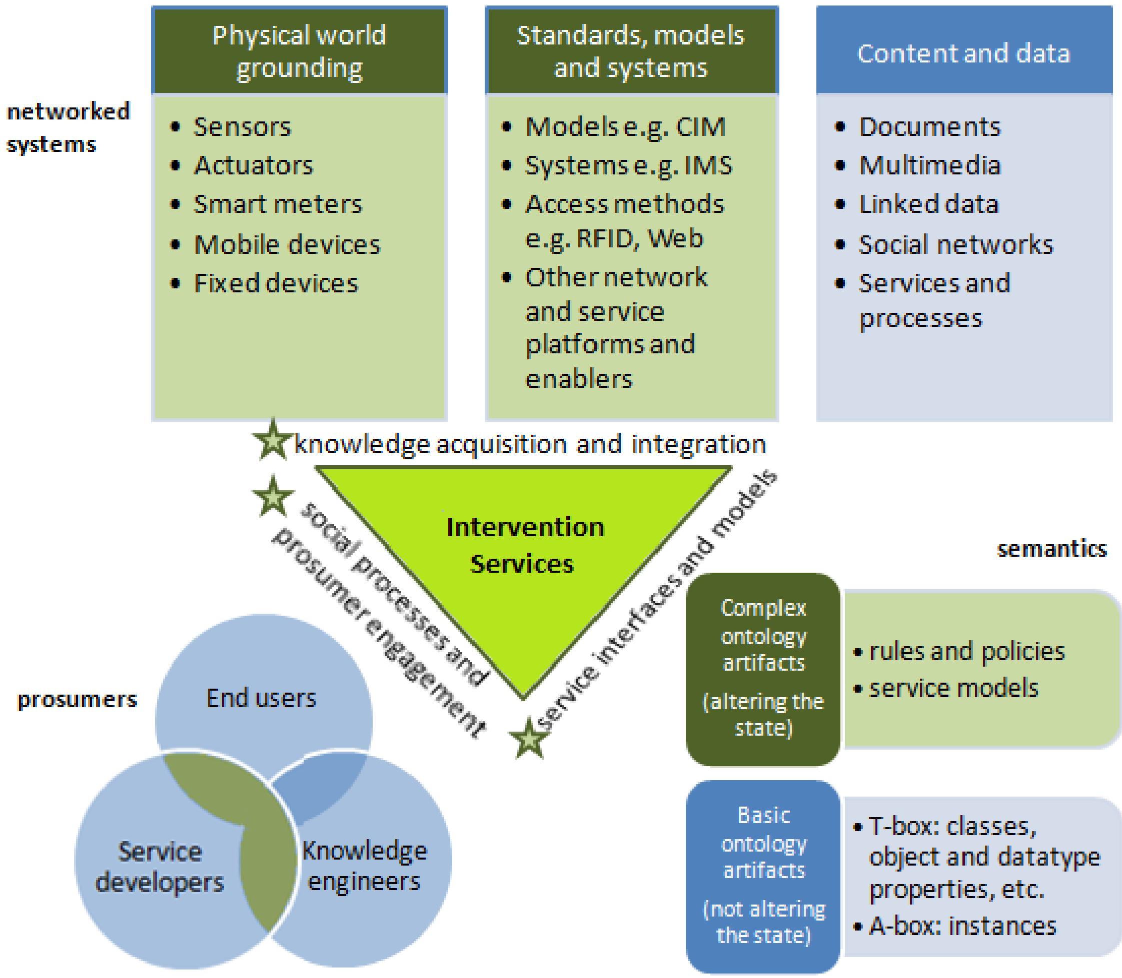

Figure 1: An intervention services approach based on semantic data intelligence

The proposed participatory services construction approach is comprised of the essential building blocks (see building blocks surrounding the “Intervention Services” central triangle of the Figure 1), namely:

1. Prosumers, constituted of overlapping networks of end users, service developers, knowledge engineers – the bottom left part of the Figure 1,
2. Semantics (ontology models, simple and complex ontology artifacts) – are the lower blocks on the right of the Figure 1,
3. Physical world grounding, existing enablers and systems (e.g. telecommunication and energy efficiency systems and enablers, social software), as well as basic data, content, as wells as conventional services and their processes – comprise the upper blocks of the Figure 1.

Centrally, all these blocks are conglomerated in the concept of the networked participatory services.

The evaluation of the development's success is primarily user-oriented, in particular, in terms of:

- increase in quality of experience (overall user satisfaction, new contacts and persistent interactions, openness, larger service choice, easiness of search and usage, etc.) and
- efficiency, or, decreased costs (in terms of time, effort, money, other resources spent for addressing the technical issues e.g. complexity or computation challenges) for the converged services, also particularly, when scaling up (adding new data, interfaces, users).

Graphical user interfaces and experiment settings applicable for technology showcasing have been designed on the basis of the derived requirements and methodologies, followed by extensive user studies.

Further, where applicable and possible, the designed systems and services are probed to be deployed in commercial settings with industry, and are evaluated regarding their business potential.

3 Examples

In this part of the paper, I discuss potential ICT solutions investigating Smart Data enablers in the domain of energy efficient buildings (OpenFridge experiment). Further, I overview our completed and ongoing work, namely, in the areas of the impact of Big Data on society and related research roadmapping (linking to sociology), personalized energy efficiency data management services in buildings (linking to psychology), and semantic data licensing (linking to law).

3.1 OpenFridge – Internet of Things Data Publishing and Service Ecosystem

Addressing the behavioural change with Smart Data, innovative directions include potential ICT solutions investigating the domain of energy efficient buildings. Particularly, our completed OpenFridge experiment [Fen16] belongs to this category. It comprised design and development of the Internet of Things data system with semantic and data analytics enablers for building new services on a top of typical home appliance data — in particular, refrigerators. The system has been evaluated with real life end-user pilots, and the experiment data has been published openly in a semantic format.

The summary of the OpenFridge project is as follows:

"*While the mass consumers' demand and expectations in the energy efficiency field grow, the providers and manufacturers of electrical appliances are searching for the approaches and infrastructures enabling them to build new kind of added-value services, based on the large volumes of data available from the appliances. Thus, the goal of the project OpenFridge is to design and develop a pilot simple and scalable Internet of Things data infrastructure, empowering building new services based on the typical home appliance data, e.g. data on the energy consumption of the fridge. The infrastructure is comprised of semantic domain models for opening of the appliances data, data analytics module for aggregation of the raw Internet of Things energy data in adding value energy efficiency information, as well as provisioning of this information to interested stakeholders (appliance manufacturers, end users, utilities, municipalities, etc.) under the new access mechanisms and business models.*"

3.2 Personalized Energy Efficiency Services in Buildings

To extend the topic of the intelligent energy efficient buildings that involve end users, the project ENTROPY - Design of an innovativE eNergy-aware it ecosysTem for motivating behaviouRal changes towards the adOption of energy efficient lifestYles[3] is being currently conducted. The technical development is advancing the field of intelligent building systems, where semantic data and rules has already been applied in real world settings, see e.g. [Kum13]. Further, the work here is conducted together with a team of psychologists that take part into designing of energy efficiency recommendations for the users, taking into account their personality profiles.

The summary of the ENTROPY project is as follows:

"Taking into account the fact that buildings constitute the largest end-use energy consuming sector, the design and development of solutions targeted at reducing their energy consumption based on the adoption of energy efficient techniques and the active engagement of citizens/occupants is considered crucial. Innovative solutions have to be implemented upon properly understanding the main energy consuming factors and trends, as well as properly modeling and understanding the citizens' behaviour and the potential for lifestyle changes.

The ENTROPY project addresses this challenge by building upon the integration of technologies that facilitate the deployment of innovative energy aware IT ecosystems for motivating end-users' behavioural changes and namely: (1) the

[3] ENTROPY project: http://entropy-project.eu

Internet of Things that provides the capacity for interconnecting numerous devices and applying energy-efficient communication protocols, (2) the evolution of advanced Data Modelling and Analysis techniques that support the realization of semantic models and knowledge extraction mechanisms and (3) the Recommendation and Gamification eras that can trigger interaction with relevant users in social networks, increase end users' awareness with regards to ways to achieve energy consumption savings in their daily activities and adopt energy efficient lifestyles as well as provide a set of energy efficient recommendations and motives."

Some of the ENTROPY results have been already published, e.g. the design of the semantic part of the system and the designed ontologies [Sim16].

3.3 Big Data Research and Policy Roadmap for Society

Obviously, Big Data and its handling has an immense impact on the society. Particularly, the related research and policies are crucial for successful development of the society. To address this direction, the Big data roadmap and cross-disciplinarY community for addressing socieTal Externalities (BYTE) project has been run to "*assist European science and industry in capturing the positive externalities and diminishing the negative externalities associated with big data in order to gain a greater share of the big data market by 2020*".

The BYTE project has produced the research and policy roadmap, as one of its key outcomes. The research roadmap has been published in a compact version, containing the key findings [Cuq16]. As a further outcome of the project, a sustainable, open for everyone to join and participate, community has been established: BYTE Big Data Community - BBDC[4]. The community promotes the implementation of the BYTE research and policy roadmaps and advocates responsible use of Big Data.

3.4 Semantic Data Licensing

Last, but not least, for the efficient data reuse, enabling semantically annotated data licenses is important, as they can facilitate the correct legal (re-)use of the data. Currently, such languages and tools are being developed the Permissions and Obligations Expression (POE) Working Group at at W3C[5], and in particular within the project DALICC – Data Licenses Clearance Center[6].

The summary of the DALICC project is as follows:

"*The creation of derivative data works, i.e. for purposes like content creation, service delivery or process automation, is often accompanied by legal uncertainty about usage rights and high costs in the clearance of licensing issues. The DALICC project aims to develop a software framework that supports the automated clearance of rights issues in the creation of derivative data works. In essence, DALICC helps to determine which information can be shared with whom to what extent under which conditions, thus lowering the costs of rights clearance and stimulating the data economy*."

4 Conclusions and Future Work

Designing, development and deployment of intervention services are discussed. They are based on semantic technology as a Smart Data enabler for individuals and organisations to participate productively by attaining new roles, and making existing roles easier. The proposed solutions on the three levels - modeling, knowledge acquisition and integration, and social processes and prosumer engagement – have been designed and deployed in real life settings jointly with the industry partners interested in the added value of the service applications.

Future research should be continued in the design and development of semantically-enabled systems that empower new types of added value services and the corresponding innovation in the service-based sectors. While the work so far has demonstrated the feasibility of such systems and the core infrastructure has been designed and developed, new network systems and enablers, as well as communication practices, will appear over time, and will require meaningful integration. Possible future research aspects could include design and development of knowledge-based services, particularly, addressing:

- Further scenarios involving heterogeneous multiple stakeholders, including establishment of relevant dynamic business and licensing models, data value chain,

[4] BYTE Big Data Community: http://new.byte-project.eu/byte-community/

[5] POE group at W3C: https://www.w3.org/2016/poe/wiki/Main_Page

[6] DALICC project: https://www.dalicc.net

- Improvement and optimization of the information and service processing infrastructures, particularly, their performance, also, basing on new directions such as Big Data [Gir14],
- Changing and steering behavior in engagement of users or customers,
- Enabling participation vs. yield management and resilience, as the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation (e.g. advancing the techniques of handling churn rates such as in customer relationship management).

Although the current work has embraced the core principles and technologies to enable semantic data intelligence for behavior changing services, the overall complexity of meaningful interoperation of humans and machines leaves much work to be done.

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