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Open semantic service networks

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Abstract:

Online service marketplaces will soon be part of the economy to scale the provision of specialized multi-party services through automation and standardization. Current research, such as the *-USDL service description language family, is already defining the basic building blocks to model the next generation of business services. Nonetheless, the developments being made do not target to interconnect services via service relationships. Without the concept of relationship, marketplaces will be seen as mere functional silos containing service descriptions. Yet, in real economies, all services are related and connected. Therefore, to address this gap we introduce the concept of open semantic service network (OSSN), concerned with the establishment of rich relationships between services. These networks will provide valuable knowledge on the global service economy, which can be exploited for many socio-economic and scientific purposes such as service network analysis, management, and control.

1 Introduction

In recent years, services have generated a tremendous interest and uptake by researchers and by the industry. Robert Morris, Vice-President of Service Research at IBM, presented a keynote at the SRII 2011 Global Conference clearly stating 'that the future is moving to services; services are becoming compulsory and will take over the economy'. Extensive research has been done on services from a *sales, communications and business models perspective* (e.g. [ZBG08]), a *software and IT perspective* (e.g. [Erl05, CM12]), and a *design perspective* (e.g. [NRJK08]). As also observed by Chesbrough and Spohrer [CS06], *"the abundance of information about people, technological artifacts and organizations has never been greater, nor the opportunity to configure them meaningfully into service relationships that create new value"*. To realize this new form of value co-creation, the authors highlight the enabling role of Information and Communication Technologies (ICT), and service management, design and engineering.

As a next logical step, current developments are targeting the computer-understandable description of business services using comprehensive languages such as *-USDL (the Unified Service Description Language)[CBMK10, BO12]. Three versions of USDL [1][2][3] are available and vary in completeness and expressiveness. In the near future, these languages will allow to formalize business services and service systems in such a way that they can be used effectively for dynamic service outsourcing, efficient SaaS trading, and automatic service contract negotiation. For example, Linked-USDL builds on Linked Data principles to ensure that service descriptions are published in a way that they can be exploited 'easily' in distributed and heterogeneous environments. Other influential efforts to better understand real-world services include the e^3* approaches. E^3value [ABG$^+$04] is a set of ontologies and methodology for analyzing the viability of e-business models. E^3service [RZDLGA12] enables an interactive composition of multiparty service networks based on e^3value-ontologies.

Current work targets the description of services which will be publicized on standalone marketplaces [CR11] and corporate Web sites. As a result, services will live in silos and it will not be possible to construct computer-understandable network models mirroring global service networks. Complementary, disjoint, equivalent, dependent, related, and similar services will exist on a number of online marketplaces without being related in any way. For the concept of service network to be materialized, the notion of open and rich service relationship needs to be explored and, afterward, the dynamic (re)creation and analysis of service networks needs to be supported by appropriate IT mechanisms. This analysis can be used to reason on a wide spectrum of data such as transactions, service descriptions, dynamic changes in services offer and demand, and service-service and agent-agent relationships. An equally important area of research is related to studying the interactions enabled by relationships and how these interactions can be analyzed for measuring social trust. This takes a special relevance since in service-dominant contexts services are a result of co-creation between all parties including providers and consumers. Vargo et al. [VL04], and others, have also perceived that we are moving into a service-dominant society. Nonetheless, our knowledge on how global service networks operate is reduced and comes mainly from the field of supply chain management.

In this paper, we focus on the particularly challenging task of constructing *open semantic service networks (OSSN)* by accessing, retrieving, and combining information from *service* and *relationship models* globally distributed. Services, relationships and service networks are said to be *open* when their models are transparently available and accessible by external entities[4] and follow an open world assumption. This represents one of the core principles of the Semantic Web and enables the dynamic addition of new service facts to a knowledge base at any point in time. In logic,

[1] α-USDL = `http://www.genssiz.org/research/service-modeling/alpha-usdl/`
[2] USDL = `http://www.w3.org/2005/Incubator/usdl/`
[3] Linked-USDL = `http://linked-usdl.org/`
[4] See the definition for the concept `open` at `http://opendefinition.org/`

this principle states that if a fact is not present in the knowledge base then its truth-value is unknown. Networks are said to be *semantic* since service and relationship models can be represented by using shared models, common vocabularies, and semantic Web theories and technologies. The ability to construct service networks is the most basic requirement to understand the dynamics of global service-based economies. However, currently available techniques fall short of providing workable solutions as they are unable to deal with the establishment of open and rich relationships between services.

We take the challenge of developing a novel perspective on the global economy by connecting service models representing open business services (e.g. consulting, e-governmental, SaaS and educational services) typically provisioned by commercial companies and governmental agencies. The difficulties which we face in doing so differ significantly from those tackled by prior work in global distributed information integration and large scale systems. Compared to previous work in Service-Oriented Architecture (SOA), we target the study of business services which goes beyond the analysis of Web services (e.g. WSDL, SOAP, and REST) in complexity. Furthermore, SOA generally relies on top-down and BPM (Business Process Management) strategies to develop process models. We take a totally different approach: we follow a self-governing and bottom-up approach which generates network models by using relationships instead of using temporal and control-flow connectors. We will address the challenges by using exploratory techniques for overcoming hidden service information and semantic heterogeneity including:

1. **Modeling.** One of the first requirements is to be able to model services and relationships articulated by service networks. The model needs to be comprehensive and include all the important concepts that describe the internal and external structure of service systems.

2. **Integration.** To enable a global scale harvesting of knowledge on services, service relationships and service networks, models need to be open and machine understandable. The field of semantic Web can bring important contributions to address this requirement.

3. **Access and storage.** The number of service and relationship models which can potentially be available at any given time in the cloud is overwhelming. Only the use of scalable and massively parallel algorithms and platforms can access and create up-to-date data structures which mirror and account for the dynamic nature of global service networked economies. Afterwards, network mining, optimization, and reasoning will come into play.

This paper is structured as follows. In the next section we provide a motivation scenario for the importance of constructing global service networks. Section 3 provides a literature review in this emerging field of science. Section 4 provides the seven design principles to follow when (re)creating OSSN. Section 5 presents an approach that can both maximize the usage of available service information and enable the location of related services in online marketplaces. Our solution involves four research activities: 1) identification of a suitable schema, language, or ontology to model services, 2) creation of an open and rich model to represent relationships between service models, 3) populate service and relationship models, and 4) development of an infrastructure to query and access distributed service models, and dynamically construct global service networks. Section 6 illustrates the value of OSSN in the context of the FI-WARE project. Section 7 is the conclusion.

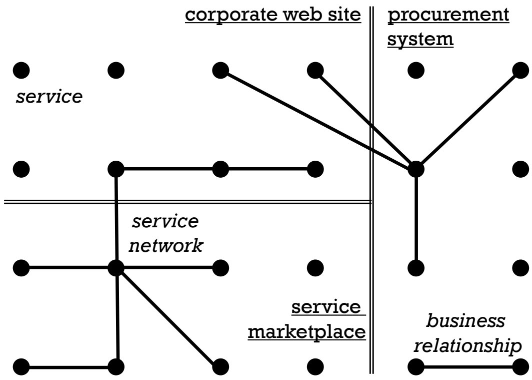

Figure 1: Services, service relationships, and service networks

2 Motivation

A *service network* can be defined as a business structure made up of services which are nodes connected by one or more specific types of relationships. Figure 1 shows the main elements of service networks and their environment. Services are illustrated by using nodes. Relationships are illustrated with edges and represent the transfer of goods, revenue, knowledge, and intangible benefits [All00]. Both the relationships and the nodes are "heavy" with resources, complex process models, interactions between stakeholders, knowledge and understanding in many different forms [HF02].

Let us consider the networked economy by looking into a specific class of service networks: financial service networks. Today's financial networks are highly interrelated and interdependent. Any disorders that occur in one service of the network may create consequences in other services of the network. For example, in 2008, the economic problems initiated a chain reaction that started in the U.S. and caused problems in European markets and took almost Iceland to bankruptcy. Leading financial services closed (e.g. Lehman Brothers investment bank), others merged, and yet new services were created. The configuration and topology of financial service networks changed as a reaction mechanism. The disaster was a surprise for most people, but local information to each financial institution and financial service was available and could have been utilized to anticipate the catastrophe. Unfortunately, the information was not accessible to regulators.

Now consider that governments had the technology and legal power to force financial institutions to describe all their financial services using machine-understandable standard description models (e.g. *-USDL). Using this approach, all the services and their descriptions would be remotely accessible to regulation bodies. Consider also that financial institutions had to indicate to which services provided by other institutions their own services established relationships with. In other words, if bank A provides loaning or consulting services to bank B, this information is also described using machine-understandable standard description models and is remotely accessible to regulators. In such a scenario, regulation bodies could at any time access and retrieve service and relationship models to (re)construct financial service networks. Afterwards, the querying and analysis of the network would enable to identify financial network's vulnerable services to protect the functionality of the network. Conflicts of interests, suspicious relationships, unlawful practices, and patterns indicating monopolies or oligopolies could be identified and trigger legal investigations to later execute reparative actions if necessary.

In a related scenario targeting consumers, financial institutions can use online marketplaces to advertise their financial services. Service marketplaces offer a practical one-stop shopping place. In this case, the development of the concept of OSSN enables consumers to better perceive the nature of the services they can acquire by understanding how they interact and relate with other services of the networked economy. A network can contrast two services with respect to potential conflicts of interests, their trust, or their position in the market (e.g. competitor or complementor).

The work presented in this paper describes the current research steps we have already made to bring these scenarios to life. For example, the family of *-USDL languages we have already developed to describe business services is explained in Section 5.1. We also depict the activities which still need to be taken in the following phases of our research project. An example of an activity is populating service and relationship models with instances which is explained in Section 5.3.

3 Literature review

In the field of services and composing services, research has been mainly done from a technical perspective by aggregating software-driven services (see [Erl05]). The goal of the research conducted was not to model service networks as the integration of economic activities, but to model the technical interfaces that need to be in place for information systems to operate in heterogeneous environments. The research carried out was from a software and IT perspective and can be classified into three categories:

- *Service descriptions* (e.g. WSDL, SAWSDL, OWL-S, and WSMO) bring various ways to describe services' interfaces using schema, models and semantics.
- *Service architectures* (e.g. SOA and SoaML) look into the organization of software-based services, how they are connected, and what service information is exchanged between consumers and providers.
- *Process models* (e.g. BPEL, BPMN, WS-CDL, and SOPHIE) use choreographies, control-flow elements, events, and temporal dependencies (e.g. S_b is executed after S_a) to define the valid sequences for the invocation of services.

When compared to previous work, research on open semantic service networks brings three new main challenging aspects to explore: (1) Service descriptions go beyond the simple description of technical interfaces specified with operations and data types (e.g. WSDL). When analyzing services as business activities, legal aspects, pricing models, marketing strategies, and quality levels need to be described. Descriptions are complex, domain dependent (e.g. healthcare, telecommunications, and energy) and aggregate, structure and configure people, resources, and information to create new value for consumers (see [BGO04]). (2) Service architectures (e.g. SoaML) are no longer confined to one or a few organizations sharing services and processes, they are open and large-scale. This means that it is not possible to assume that all existing services are known in advance when designing an architecture. Architectures are the result of a self-emerging behavior. Furthermore, OSSN are large-scale since they can involve thousands services that span worldwide, they are created autonomously, and using a bottom-up approach without a central managing entity. (3) In contrast to process models (e.g. BPEL), the main objective of OSSN is not to use control-flow elements and temporal dependencies to articulate the execution of services. OSSN capture the relationships that services – as economical activities – establish with other services. There is a shift from an execution perspective to a relationship perspective. OSSN capture how business services are related to each other in networked economies. If we understand how services evolve as complex systems and understand the type of relationships that are established in evolving and dying service networks, our knowledge on digital service-based economies will advance significantly.

On the other hand, the work from the business research field has mainly provided conceptual models for business networks which are often described in natural language (see [WV01, CR02, App01, TLT00, Par99]). They are not open, machine-readable or semantically described, and, therefore, do not constitute a solution for large scale service network analysis. A number of researchers worked on formalizing business models. For example, Weiner and Weisbecker [WW11] describe a set of models addressing value networks, market interfaces, products and services, and financial aspects. Osterwalder et al. [OPC10] presented the *business model canvas*, a simple conceptual model and graphical tool for sketching business models. Nonetheless, most business modeling approaches, including e^{3}value [ABG$^+$04], fail to adhere to service-dominant logic and focus too much inward the company instead of the network they belong to. Compared to other approaches, such as e^{3}value and e^{3}service, our aim is not to develop a communication tool for the manual analysis of well-known and established networks. Instead, we seek the global and automatic re(construction) of possibly unknown service networks to enable the large scale processing of service information. Collaborative networks [ACM05] have studied how partners can dynamically form networks to, for example, support virtual organizations. The major challenges which have still to be addressed include the selection of potential partners in an open universe and the acquisition of profile information about organizations. Our work can provide insights on how these two requirements can be satisfied using semantics, open models, and distributed data. In the other hand, our work can also benefit from the progresses made in the field of collaborative networks on the development of relationships among partners, governing rules and principles for network participation.

4 Seven design principles of OSSN

Open semantic service networks are structures created with the objective to sustain and power the digital representation, modeling and reasoning about business service networks. This overarching objective requires underlying assumptions and normative rules. Therefore, an OSSN and its construction are based on the following seven design principles:

- Service versus Web service – A business, or real world, service is a system which aggregates, structures and configures people, resources, and information to create new value for consumers. On the other hand, a Web service is a computational entity and software artifact which is able to be invoked remotely to achieve a user goal. OSSNs encompass the former.
- Social process – The (re)construction of OSSNs is the result of a peer-to-peer social process. Firms, groups and individuals (i.e. the community) are equal participants which freely cooperate to provide information on services and their relationships to ultimately create a unique global, large-scale service network.
- Self-governance – OSSNs are the common good which the community tries to create by using forms of decision-making and autonomy that are widely distributed throughout the network. A service network is governed by the participants themselves, not by an external central authority or a hierarchical management structure.
- Openness and free-access – The OSSNs created, being the elements of value created by the community, are freely accessible on a universal basis. Nonetheless, the individual authorship and contribution of services and relationships is recognized and is traced back to its originator.
- Autonomy and distribution – The participants (i.e. firms, groups, and individuals) of the community have the autonomy to advertise their know-how, capabilities and skills in the form of services to the world and to establish relationships with any other service. Services are distributed over space, time, and they come together to form new services as networks.
- Semantic networks – OSSNs are said to be semantic since they explicitly describe their services and relationships typically using a conceptual or domain model, shared vocabularies, and ideally using Semantic Web standards and techniques.
- Decoupling – Decoupling denotes that OSSNs are made of service descriptions and service relationships, but relationships are defined in isolation with respect to service descriptions. In other words, each relationship is specified independently without regard to any specific service description language, and vice-versa.

As our work advances we expect to adjust, generalize or specialize this initial list of seven design principles.

5 Approach to open semantic service networks

As described previously, our long term goal is to develop rich, open service networks and this undertaking involves four main activities:

- **Service modeling.** The creation of an ontology by identifying and modeling business service concepts. Semantic Web ontologies can be used to enrich service descriptions and to make the underlying information available to both humans and remote software applications.

- **Expressing rich service relationships.** The creation of a model for specifying connections between services. The encoding of relationships needs to be rich, include business information, and be computer-understandable, allowing an automatic extraction and construction of service networks.
- **Populating service and relationship models.** In order to enable a widespread use, there is the need to bootstrap service networks with up-to-date services and relationship instances. Crawling, Web mining, and crowdsourcing are viable options to create initial service descriptions, traces about the created service networks, and service relationships inferencing.
- **Service network construction.** The construction of service networks, globally distributed, requires service models to be accessed, retrieved, stored and integrated. Therefore, new research on parallel approaches and scalable storage systems is indispensable.

In the following sections, we will describe in detail each activity.

5.1 Service modeling

Due to the presence of mainly unstructured information about business services publicly available at corporates' Web sites, in business reports or academic studies (e.g. [KZC+04]), it is extremely difficult to identify anything substantial and significant about service models and relationships. The information available is unstructured (see for example [Fre08]), does not comply to any common semantics, and is often not easily accessible. Therefore, our work targets to address these limitations and provide building blocks using service and relationship modeling for remote access and retrieval.

In the field of service modeling, we have been working on descriptions for business services. Our previous work has produced USDL [CBMK10, BO12], the Unified Service Description Language. In the past, only the quality of physical goods and products was primarily driven by adherence to manufacturing specifications. With the introduction of USDL there is a paradigm shift which sees that the quality of services can also be represented and controlled using guiding specifications. In general, service modeling suffers from an impedance mismatch between at least two modeling perspectives which USDL integrates into one specification:

1. The business perspective adopts a service-dominant logic to understand *why* and *how* enterprises should form networks on the service Web. Resource-service dynamics describes *what* resources have to acted upon by *whom* and *how*.
2. The ICT perspective adopts service-oriented modeling as a paradigm to automate business network interactions. Web service modeling aims at the interoperability of communication protocols (e.g., SOAP, REST) and data formats between heterogeneous *service parks*.

USDL bridges a business, an operational and a technical perspective. The language models service concepts and properties such as service level, pricing, legal aspects, participants, marketing material, distribution channels, bundling, operations, interfaces, resources, etc. It provides a comprehensive view on services.

The initial version of USDL was ready in 2009. It was later renamed to α-USDL (pronounced alpha-USDL). Based on the experiences gained from α-USDL, a W3C Incubator group was created and USDL was adapted and extended based on industry feedback. This second version was finalized at the end of 2011. In order to make the specification gain a wider global acceptance, a version called Linked-USDL emerged using semantic Web principles and its development is still in progress. The term Linked-USDL should not be confused with the idea that the language attempts creating relationships between services. The goal of Linked-USDL is to develop an ontology to represent services by establishing explicit ontological links to other existing ontologies emerging from Linked Data initiatives. This is the reason for using the term *linked*. Linked-USDL was designed based on Linked Data principles and practices for the following reasons:

- Retain the necessary simplicity for computation as well as for modeling purposes.
- Reuse existing vocabularies to maximize the compatibility of related systems, reusability of previously modeled data, and reduce engineering efforts to build complex models.
- Provide a simple – yet effective – means for publishing and interlinking distributed data for an automatic computer processing.

While the Linked-USDL has been initially constructed to describe business services, our analysis revealed in a preliminary study that it can be used to model services and service networks by adding rich, multi-level relationships. Linked-USDL is suitable to support the concept of open service systems and makes service information accessible to remote and heterogeneous software applications which can retrieve and align service models into service networks for various exploratory uses.

At present, work done in the domain of service modeling, such as *-USDL service description languages, has tackled services as single atomic entities and groups of services (i.e. service bundles). Without additional research, these languages will lead to the construction of service marketplace silos where a wealth of information on economic activities will be available but with no information on service relationships. Without information on relationships between services available, it will not be possible to harness sufficient knowledge to construct service networks. The study and formalization of relationships is examined in the next section.

5.2 Expressing rich service relationships

Our approach will connect service models hosted in marketplaces, corporate Web sites, and procurement systems using a computer-understandable format. The existence of tangible relationships between companies has been observed in a range of studies over the past 25 years, but the phenomena of service systems was discovered only recently [HF02]. Nonetheless, its profound importance for society has already attracted a remarkable attention from academia and industry. What is needed is to be able to represent and identify richer service relationships between services, so that the richness of the real world is not crammed inaccurately and inappropriately into very limited and inexpressive types of relationships. For example, in the field of Semantic Web, simple relations provided by RDFS and OWL – such as `rdfs:subClassOf`, `owl:EquivalentClass`, `rdf:seeAlso` and `owl:sameAs` – are strict and limited relationships which are not suitable to connect all the world's services.

In order to develop a model for rich service relationships, research from the areas of business management and supply chain networks is required. For example, Weill and Vitale [WV01] have introduced a set of simple schematics intended to provide tools for the analysis and design of business initiatives based on participants (firms of interest, customers, suppliers, and allies), relationships, and flows (e.g. of money, information, products, or services), which may provide a baseline for the work which needs to be done on service networks. In the same lines, Bovet and Martha [BM00] have also provided research results which need to be considered in our approach. They propose the concept of value net to define a network of partnerships which is a dynamic, high-performance network of customers/supplier partnerships and information flows. The e^3value and e^3service approaches have already identified a few relationships such as value exchange, core/enhancing and optional bundling (see [ABG$^+$04]).

Nonetheless, relationships should be more expressive than simply establishing the added value of services when bundled together. Organizational, strategic, process and activity, social, KPI dependencies, and cause-effect relationships also need to be considered. Spohrer and Maglio [SM10] define the Initiate-Service-Propose-Agree-Realize (ISPAR) typology of interactions that may occur between service systems. Some of them are directly value-creating (such as proposing, agreeing and realizing the service), also called value interactions; while others are not qualified to create value (such as disputes). Analysis of interactions may give insights in the evolution of service systems. Since these research streams are relevant, it is indispensable to explore their use and applicability for service networks.

We propose to develop a core open semantic service relationships model called OSSR which defines the main concepts and properties required to established rich, multi-level relationships between service models encoded using Linked-USDL. In other words, services will be described with Linked-USDL and connected with OSSR. Our idea behind the formalization of service networks is pragmatic and it is based on the objective of creating a connected global service network using computer-understandable descriptions. OSSR aims to meet the needs of service stakeholders as service-centric platforms (e.g. marketplaces, procurement systems, corporate Web sites, service blogs and forums, etc.) become more prevalent on the Internet. Finding relevant relationships among service will become more important than ever for service providers and consumers.

Open and rich relationships are very different from the temporal and control-flow relations found in business process models (e.g. BPEL, BPMN, Petri nets, EPC). Once constructed, they are open and can be freely and individually accessed and retrieved over the Web. They are rich since they relate two services using a multi-layer model which enables to indicate, for example, the role of services in a network (e.g. provider, consumer, competitor, or complementor), the strength of a relationship (e.g. high or low), if a service depends on another service for its survival, the comparison of two services based on the number and types of operations provided, and the types of resources transfered between services (e.g. data, knowledge, physical resources, or financial).

To improve the quality of OSSR formalization and integration with other Semantic Web initiatives, we will follow the same path as the one taken by Linked-USDL: we will establish links with various existing ontologies to reuse concepts from vertical and horizontal domains such as SKOS (taxonomies), SIOC (interlinked communities), Dublin Core (documents), GEO (geographic coordinates), and so on.

5.3 Populating service and relationship models

When we think about applying the open service network concept at a global scale, a thorny question immediately arises: "how will service and service relationship models be created?". This aspect is important since to enable a widespread usability of service networks there is the need to bootstrap up-to-date services and relationship instances. Previous approaches typically collected business data manually from survey firms, teardown reports or on-site analysis (e.g. Dell supply chain analysis [KZC$^+$04] and Apple's iPod networks [LKD09]). These methodologies are not suitable to be applied to study global service networks.

Service and relationship models can be acquired using manual and automated methods. Manual approaches can rely on crowdsourcing initiatives. By allowing service providers and other stakeholders to manually create explicit, rich relationships between different service models, open service networks can incrementally grow in size and, ultimately, become global. We also believe that the snowballing process described in [CET07] applies to our work and will happen transparently. Firms may wish to only identify suppliers. When this occurs in all the nodes of a service network, worldwide networks will become available. Automated methods, e.g. by using Web scraping and wrappers, can crawl unstructured service sources from the Web, such as corporate Web sites and marketplaces (e.g. ServiceMagic.com, Sears' ServiceLive.com, ServiceAlley.com, and Redbeacon.com), and create models on-the-fly. Experiments on harvesting service descriptions from an online catalog containing e-learning material were performed in [RZGDLA11].

Relationships can also be identified by inferring or deriving similarities between service providers, service models and service marketplaces. For example, let us consider the following rule. Infer implicit service relationships if: 1) a set of services is provided by the same organizational department, 2) if two services have the same goal or 3) if they target the same customer profile. The use of industry segments and supply chains to relate services is also an approach to explore.

5.4 Service network construction

Once service and relationship models are populated and published as Linked Data principles (see previous section), the access and retrieval of distributed models from the Web require parallel approaches to fetch service and relationship models and distributed solutions to store and (re)construct service networks. We will achieve scalability by merging two state-of-the-art developments resulting in a novel crawling and storage system. We will couple LDSpider [IHUB10], which provides load-balancing capabilities, with the Sesame RDF repository (studies have shown that Sesame and Virtuoso are some of the fastest semantic-based repositories).

On the one hand, LDSpider – an extensible Linked Data crawling framework – can enable to traverse and to concurrently consume distributed service models. LDSpider will need to be extended to implement specific crawling strategies. For example, new crawling algorithms that consider only specific types of rich service relationships and domain specific business knowledge to retrieve models can be designed and implemented to increase efficiency.

On the other hand, there is the need to extend current RDF repositories, such as Sesame, using similar approaches to the one followed in [SHH$^+$11], i.e. by applying a federation layer as an extension to Sesame. Several other approaches for storage, such as Jena SDB, are used in conjunction with a traditional DB like MySQL to provide a triple store. These approaches are inefficient since they provide costly mechanisms specific to databases which are not necessary for RDF stores (e.g. multiuser, table-orientation, primary and secondary keys, etc.). Furthermore, service discovery requires transforming customer needs into concrete service offerings and should not rely on traditional low level querying mechanisms to express desired services.

Having this infrastructure and machinery in place, service networks can be discovered and become accessible as massive distributed information systems which enable the development of efficient algorithms to analyze, mine, reason and optimize service networks.

6 Application field

While the main motivation scenario from Section 2 was drawn from financial networks, here we show the use of OSSNs in the context of cloud-based services to demonstrate the wide range of applicability of service networks.

The FI-WARE[5] project, part of the EU Future Internet PPP program, aims to deliver a service infrastructure which offers reusable and shared functionality for service oriented businesses in the cloud. The *Application and Services Ecosystem and Provisioning Framework* focuses on business aspects of service ecosystems such as describing and exposing services, aggregation and composition, service marketplaces, business models, execution and revenue sharing. Open semantic service networks are a valuable concept which provides a new dimension to analyze, control and innovate business models out of existing services and their relationships.

For marketplaces, OSSNs provide a rich knowledge base to derive information for service discovery and matching offering and demand. Because a service is connected to other services and other business elements (providers, suppliers, partners, competitors, etc.) via a OSSR, the marketplace can utilize this information to achieve a more effective matchmaking. Since FI-WARE marketplace provides a wide range of functionalities, it can advance beyond matching and improve, for example, recommendations, ratings, market intelligence, and price calculation support. OSSNs can also constitute the underlying distributed model for SAP's Business Web to combine services from cloud providers, telecommunication carriers, and application and content providers, and serve as a network mirroring mobile business on the Internet.

While current business modeling efforts (e.g. [WW11, OPC10, ABG$^+$04]) provide guidelines for developments surrounding open semantic service networks, other important aspects need to be considered in detail. On the one hand, the models need to be brought into the Linked Data realm in order to unleash their full potential. This means that they have to be harmonized with other descriptions such as Linked-USDL. On the other hand, previous approaches using semantic business models are theoretically sound but often too complex to be used by practitioners. Researchers

[5] `http://www.fi-ware.eu/`

have tried to hide complexity by providing graphical environments such as moby:designer[6]. However, most business models cannot be manually modeled due to their inherent complexity and lack of global information available. They will emerge in a bottom-up fashion from actual businesses by mining service and relationship models.

7 Conclusions

Open semantic service networks present an entirely different class of challenges not faced by the large body of prior work in services. The primary challenge stems from the fact that currently business services' information is often hidden in unstructured marketplaces and corporate Web sites, and no information about service relationships between services is available. Therefore, to construct service networks, three premises need to be fulfilled. First, the information on service models needs to be open and remotely accessible. Second, models need to be related using rich, open semantic service relationships to handle the heterogeneity of the Web and business industries. Third, the construction of service networks by using rich relationships needs capable and massively parallel platforms for querying, integrating and aligning service models.

In this paper we presented an approach addressing these requirements to support the concept of open semantic service networks. Our proposal uses *-USDL to model services and proposes the development of a new model to represent rich service relationships following the genesis of Linked-USDL. The formalization of rich relationships is an under-explored field of research but of utmost importance to understand global economies. Applications of the combination of models proposed in this paper carry potential for many exploitations where service models need to be bridged such as service network analysis, businesses model generation, and supply chain optimization.

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