Enhancing Enterprise 2.0 Ecosystems Using Semantic Web and Linked Data Technologies: The SemSLATES Approach

Alexandre Passant, Philippe Laublet, John G. Breslin and Stefan Decker

Abstract During the past few years, various organisations embraced the Enterprise 2.0 paradigms, providing their employees with new means to enhance collaboration and knowledge sharing in the workplace. However, while tools such as blogs, wikis, and principles like free-tagging or content syndication allow user-generated content to be more easily created and shared in the enterprise, in spite of some social issues, these new practices lead to various problems in terms of knowledge management. In this chapter, we provide an approach based on Semantic Web and Linked Data technologies for (1) integrating heterogeneous data from distinct Enterprise 2.0 applications, and (2) bridging the gap between raw text and machine-readable Linked Data. We discuss the theoretical background of our proposal as well as a practical case-study in enterprise, focusing on the various add-ons that have been provided to the original information system, as well as presenting how public Linked Open Data from the Web can be used to enhance existing Enterprise 2.0 ecosystems.

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1 Introduction

Blogs, wikis, as well as free-tagging and content syndication principles are now widely used in the enterprise, in a paradigm shift generally referred to as Enterprise 2.0 [23]. In this vision, Web 2.0 tools and their collaborative behaviours (which are now widely accepted on the Web) become part of the enterprise: *"Enterprise 2.0 is the use of emergent social software platforms within companies, or between companies and their partners or customers"*[1]. Furthermore, since the social aspect predominates, the Enterprise 2.0 vision relates to the *Information Ecology* paradigms proposed by [10], in which people play a central role in information systems.

Inside the enterprise, these tools help to enhance information sharing and collaboration between employees, with a global aim to enable collective intelligence in such structures, following the *"We are smarter than me"* idea [21]. When defining Enterprise 2.0, [23] discusses how such tools can transform intranets into dynamic and evolving structures thanks to user involvement. In addition, he characterises how Enterprise 2.0 should respond to user needs by defining the SLATES acronym:

- *Search* — Efficient information retrieval;
- *Links* — Links between (internal and external) content;
- *Authoring* — Easy publishing services;
- *Tags* — Tag-based annotation;
- *Extensions* — Discovery of new content;
- *Signals* — Identification of relevant information.

However, the services usually deployed to achieve this goal introduce various issues regarding how to efficiently use the information they help to produce. First, their nature and diversity emphasise issues regarding information fragmentation, as content about particular objects (projects, customers, etc.) is split within several tools. Moreover, their plain-text nature makes knowledge capture and reuse particularly difficult, while they generally provide valuable and consensual information, in particular within wikis. Finally, free-tagging leads to ambiguity and heterogeneity issues, also constraining the information retrieval task.

In this chapter, we discuss an approach based on Semantic Web and Linked Data technologies to solve the aforementioned issues. In particular, our approach, named SemSLATES (for "Semantic SLATES"), provides a *Social Semantic Middleware* architecture that can enhance existing information systems with these technologies [27]. It relies on different level of ontologies and metadata generated from existing Enterprise 2.0 applications, thus enabling Linked Data in Enterprise 2.0 environments, by forming a complete graph of RDF(S)/OWL annotations on top of existing information systems. Furthermore, once this additional layer of semantics has been provided, new applications can be deployed, ranging from semantic search interfaces to semantic mashups, combining internal data and information gathered from the Linking Open Data cloud, enhancing enterprise information systems by reusing public and open data from the Web.

[1] http://andrewmcafee.org/blog/?p=76

The rest of this chapter is organised as follows. In Section 2, we detail the three main issues of Enterprise 2.0 ecosystems that we briefly mentioned earlier. Then, in Section 3, we present our SemSLATES proposal, detailing (1) its global vision and architecture; (2) the ontologies it requires; (3) how existing applications can generate the related data; and (4) how new services can be deployed using it. We then present a related case-study of the SemSLATES implementation at Électricité de France (EDF) Research and Development[2] in Section 4 and we particularly focus on the ontologies we designed, the plug-ins that have been developed, as well as the additional services that we have engineered. Furthermore, since the motivations of our work came from that particular case, the issues described in Section 2 are back-ended by some figures gained in this context [26]. Finally, we conclude the chapter, also discussing how the approach can be extended with further data, such as mobile information or sensor networks deployed in the enterprise.

2 Issues with Current Enterprise 2.0 Ecosystems

As mentioned in the introduction, Enterprise 2.0 can be defined through the SLATES acronyms, and blogs, wikis, RSS feeds — among others — aim to achieve this goal of collaborative knowledge management. However, while they definitely help to reduce the burden of creating and sharing information in the enterprise (simple interfaces, open access, etc.), they raise various issues regarding how to efficiently use this information. To that extent, we believe that Mathes' views regarding folksonomies (*"a folksonomy represents simultaneously some of the best and worst in the organization of information"* [22]) can be applied to Enterprise 2.0 ecosystems in general: more and more information becomes available, but it becomes more and more difficult to make sense of it.

To defend this opinion, we now detail three main issues of Enterprise 2.0 ecosystems, based on our experience at EDF R&D : (1) information fragmentation and heterogeneity of data formats; (2) knowledge capture and re-use; and (3) tagging and information retrieval. In this chapter, we only focus on the technical issues of Enterprise 2.0 systems. There are however other — more social — issues that must be considered to make such systems successful, especially in organisations where generally *"knowledge = power"*. For instance, in our context, we observed that some users were reluctant to open-up their wikis, while they finally changed their mind when realising that other open wikis received valuable contributions. These relationships between the corporate culture and adoption of Enterprise 2.0 principles have also been observed by an AIIM study indicating that 41% of respondents do not have a clear understanding of Enterprise 2.0, as against only 15% for companies with a knowledge management background [11]. Thus, it is important to keep in mind that more than a set of tools and technical prerequisites, Enterprise 2.0 is a

[2] EDF is the major electricity company in France — see http://rd.edf.fr for details.

philosophy that can sometimes takes time to be accepted, as noted by Dion Hinchcliffe: *"Enterprise 2.0 is more a state of mind than a product you can purchase"*[3].

2.1 Information Fragmentation and Heterogeneity of Data Formats

Information sharing and social networking in organisations is generally object-centric: people publish and browse information about particular objects such as projects, research topics, customers, etc. This relates to the "object-centred sociality" idea [18] that can also be observed on the Web (*e.g.* people connecting through musical artists in last.fm). While some Enterprise 2.0 information systems are provided using dedicated suites, such as IBM Lotus Connections[4], they generally consist of an aggregation of services fragmented over a company network. Indeed, the heterogeneity of people and topics in organisations often leads to different ways to share information and hence to different applications being deployed: some people may only need an RSS reader, other will require a wiki or a blog, etc. Furthermore, these services might be setup at different times, which make them even more heterogeneous (some software architectures may becomes obsolete and are consequently replaced by new ones, etc.).

As a consequence of the fragmentation of services and applications, data and knowledge about particular objects is often spread between various sources in the company network. For example, the description of a project and its deliverables can be edited on a wiki but the latest project news may have been blogged and commented about on another platform, while RSS feeds may also contain valuable information regarding the project partners. Consequently, knowledge workers must query different sources of information to get the global picture regarding a particular topic. Most importantly, users must know that these sources exist in order to be able to reach them — which is not always the case, especially in large-scale organisations. Furthermore, different applications imply different APIs and data formats. Hence, information integration is a costly task for developers.

While this is not a new issue *per se*, Enterprise 2.0 strengthens information fragmentation since it provides users with new means for publishing content, thus enabling more and more distributed and heterogeneous data, locked in walled-garden applications that do not interact each other. As an example, in our environment, more than 200 users where involved in the creation of more than 4,700 wiki pages and 21,000 blog posts, over a three years period.

[3] http://blogs.zdnet.com/Hinchcliffe/?p=143

[4] http://www-01.ibm.com/software/lotus/products/connections/

2.2 Knowledge Capture and Re-use

Wikis are used in many organisations as a way to collaboratively build open and evolving knowledge bases, in areas ranging from project management to software development. Yet, while they contain much valuable information, software agents cannot easily exploit and reuse it easily. A reader could learn from a wiki that EDF is a company producing nuclear energies in France but an application will not be able to easily answer requests such as *"Is EDF located in France?"* or *"List all companies referenced in this wiki"* without using complex Natural Language Processing algorithms. The main reason is that wikis simply deal with documents and hyperlinks and not with machine-readable of real-world concepts, as understood by readers when they are browsing or editing a page. A wiki engine will indeed store the fact that *"There are some hyperlinks between a page titled "EDF", a page titled "France" and a page titled nuclear "energy""*, but it will not be able to deduce anything about the nature of those different objects and their relationships, since the pages do not carry enough semantics about the knowledge they contain, *i.e.* focus on a *document-centric* view rather than on a *data-centric* one.

Hence, there is a gap between documents and their interpretation. Consequently, users must parse and read all the pages from a wiki to answer such queries, which can be a time-consuming task. Moreover, user interpretations can be biased and different depending on their cultural and technical backgrounds.

2.3 Tagging and Information Retrieval

Tagging is a well-known practice on Web 2.0 websites and consists of the attachment of multiple free-text keywords or "tags" as metadata to created content. Tags are often used as a means of categorising similar content from various users for later retrieval and browsing. In addition, an important feature of tagging is its collaborative aspect, since tags can be shared between people, and are often used to retrieve and browse documents produced by others. The collection of these tagging actions and keywords created by many users is generally known as a folksonomy [39].

The limits of free-tagging approaches are mainly due to tag ambiguity and heterogeneity as well as a lack of organisation between tags [22] [34]. Consequently, while tagging can be a time-saving method for end users when publishing and categorising content — since they do not have to apprehend a pre-defined classification — it becomes costly when trying to retrieve relevant information. For example, since tag-based search engines are plain-text only, someone looking for items tagged *"social_software"* will neither get those tagged *"socialsoftware"* (spelling variant) nor *"logiciel_sociaux"* (linguistic variation), and they will not be able neither to find specific tags such as *"wiki"*. While clustering approaches can be used in some cases [2], an analysis of our organisational folksonomy raised other interesting issues regarding that topic.

First, as in many systems, most of the tags used in our blogging platform were used only a few times. In a total of 12,257 tags — used within 21,614 blog posts — it appeared that more than 68% were used twice or less, while only 10% were used more than ten times. As [15] has reported, tag clustering may not be adapted for this kind of distribution, unless combined with other techniques such as, for instance, taking into account the underlying tagged information. This is also a complex issue if dealing with non plain-text documents, such as PowerPoint files or diagrams that can be exchanged in corporate blogging platforms.

In addition, another lesson learnt from our folksonomy analysis is that users tag differently depending on their level of expertise and that these differences in tagging behaviours also raise several issues when retrieving content. For instance, we identified that experts in solar energies used specific tags such as *"TF"*[5], while non-experts would use generic ones like *"solaire"*[6]. This relates to the different "basic levels" of knowledge that people have regarding given domains [38], as also raised by [12] when analysing tagged content from Delicious. Furthermore, we identified that experts often did not use any broader terms when tagging content. Only 1% of the 194 items tagged with *"TF"* in our system were tagged together with *"solaire"*, while less than 0.5% of the 704 items tagged with *"solaire"* were tagged with *"TF"*.

Hence, clustering algorithms cannot be efficiently used to find related tags since they are too weakly related, as discussed in [2]. Thus, lots of valuable content (*i.e.* created and tagged by experts) cannot be retrieved by non-experts, as they use generic keywords in their queries. This entails a real problem in terms of knowledge sharing inside organisations and limits the possibilities offered by these collaborative platforms: most of valuable information (*i.e.* produced and tagged by domain experts) is lost as it cannot be easily retrieved by non-experts.

3 SemSLATES: A Social and Semantic Middleware Approach for Enterprise 2.0

While we agree that most Enterprise 2.0 tools ease the *Authoring* process (from the SLATES acronym), we have shown in the previous section that they are somehow limited regarding some other features, especially *Search* and *Extensions*. To solve these issues and to offer new value-added services to end-users, our proposal consists of using Semantic Web technologies (*i.e.* RDF(S)/OWL, SPARQL, etc.) and Linked Data principles, to enable (1) interoperability between heterogeneous Web 2.0 applications in the enterprise, (2) knowledge capture — by bridging the gap between *documents* and *data* — , and (3) better information browsing and querying *via* additional applications using this machine-readable and structured data. In particular, our approach focuses on:

[5] An acronym for *Thin Film*, a particular kind of solar cell.

[6] French for *solar*.

- using lightweight semantics and simple add-ons producing Linked Data from existing tools, rather than building a new monolithic application that would require to rethink existing information systems;
- re-using existing models and data already available on the Web, hence (1) bridging a gap between the open Web and Enterprise 2.0 information systems and (2) taking advantage of structured data available on the Web (especially from the Linked Open Data Cloud) to enrich Enterprise 2.0 information systems;
- considering users as the core component of the system, by being producers and consumers of semantic annotations, hence strongly emphasising the collaborative side of Semantic Web-enabled knowledge management.

This additional stack of semantics on top of existing Enterprise 2.0 information systems led us to define SemSLATES, *i.e.* "Semantic SLATES", demonstrating how Semantic Web technologies can enhance the SLATES approach (Table 1). By applying the SemSLATES principles to existing Enterprise 2.0 systems, a query such as *"List all the blog posts written last week about a project involving a company based in France"* can be answered, while it cannot be carried out using current Enterprise 2.0 systems.

	SLATES	**SemSLATES**
Search	Plain-text search	Semantic search based on RDF annotations
Link	Hyperlinks between documents	Relationships between resources
Authoring	Documents	Data and metadata
Tags	Tagging	Semantic indexing based on ontologies
Extension	Hyperlinks navigation	RDF graph-based navigation
Signals	RSS feeds	Semantically-indexed RSS feeds

Table 1 SemSLATES: Extending SLATES using Semantic Web and Linked Data technologies.

3.1 The SemSLATES Architecture

In order to achieve the SemSLATES vision, there is a need to provide an additional layer of semantic annotations on top of existing Enterprise 2.0 systems, thus "linking enterprise data" [37] and enabling a new area of Semantic Enterprise 2.0 information systems, since this layer provides the meaningful integration of data from heterogeneous components. It is also important to keep in mind that our goal is not to engineer a new knowledge management suite for Enterprise 2.0, but rather to provide means to integrate various existing components together in a transparent way for end users. Therefore, we consider SemSLATES as providing a *Social and Semantic Middleware* approach for Enterprise 2.0, enhancing existing ecosystems. To that extent, we defined a middleware process [41] comparable to the *RDF*

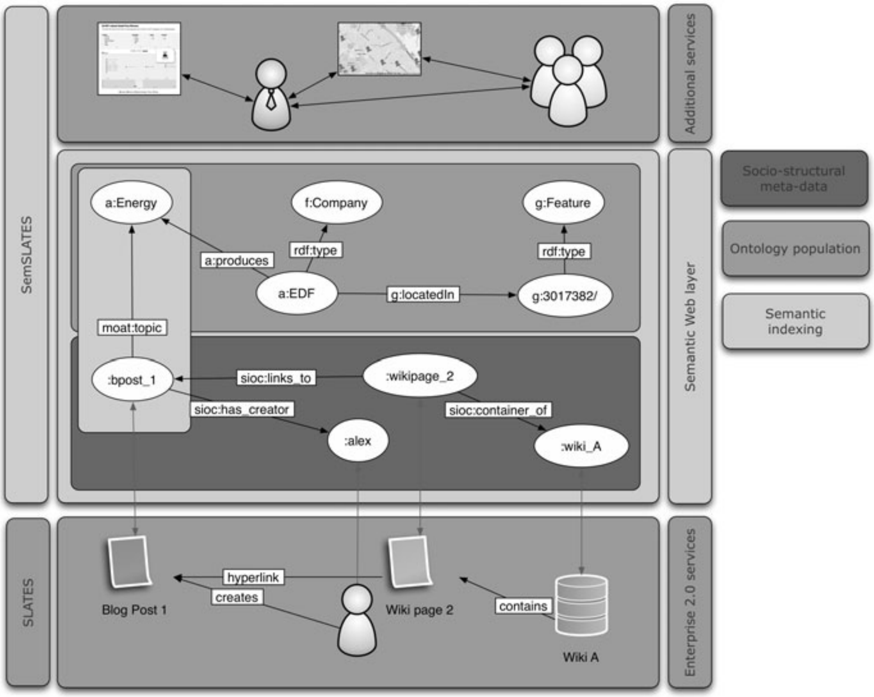

Fig. 1 The SemSLATES approach: Combining different layers of RDF(S)/OWL annotations on top of existing Enterprise 2.0 systems.

bus architecture proposed by Berners-Lee[7]: semantic annotations are produced from existing tools, and these are then interlinked and queried using Semantic Web standards (RDF(S)/OWL and SPARQL).

More precisely, various kinds of semantic annotations are required to enable this SemSLATES layer, as depicted in Fig. 1, and defined as follows:

- **socio-structural metadata** are required to model uniformly (1) structure of existing Enterprise 2.0 applications, (2) metadata about the social interactions happening between users in these applications, and (3) the resulting documents. This layer solves the issue of heterogeneous data formats and APIs between different Enterprise 2.0 applications, by offering a common representation layer for such, wherever they come from. Our vision relies on popular ontologies such as FOAF — Friend Of A Friend[8] [8] — , a lightweight ontology aiming at representing people and their social networks, and SIOC — Semantically-

[7] http://www.w3.org/2005/Talks/1110-iswc-tbl/#(26)
[8] http://foaf-project.org

Interlinked Online Communities[9] [6] — dedicated at representing online communities, their activities and contributions;
- **domain-specific ontologies and semantic annotations** are required to enable representation of the business information stored inside these Enterprise 2.0 systems (*e.g.* information about companies, projects, etc.). Here domain-specific ontologies can be used along with popular existing vocabularies [4]. In order to create the related annotations, semantic wikis are of particular interest, since they combine wiki principles (open editing, versioning, multi-authorship, etc.) and Semantic Web knowledge representation principles for a user-driven, open and evolving population of related knowledge bases, as described in more detail in [9] and [35];
- **semantic indexing** is required so as to allow content to be annotated with URIs identifying meaningful information (such as projects or people) instead of simple and unstructured keywords. This latest layer solves the issues of free-text tagging and enables links between domain ontologies and socio-structural metadata, leading to a complete interlinked graph of structured data on top of existing Enterprise 2.0 systems. It is achieved thanks to models and frameworks as MOAT — Meaning Of A Tag[10] [31] — an ontology and process to bridge the gap between free-tagging and semantic indexing.

In addition, to enable these annotations, enhancements of the original tools must be as lightweight as possible to avoid disturbing users in their existing publishing habits. Considering that transitioning from legacy information systems to Enterprise 2.0 environments can take time (in terms of user acceptance), it is indeed important to build on existing services, rather than providing new applications that can take time to be accepted. Once these enrichments have been enabled, and therefore the annotations being available, new applications can be provided, improving the whole user experience of querying and browsing information in Enterprise 2.0 settings.

To that extent, SemSLATES promotes the use of user interfaces that do not confront end-users with any of the underling modelling features (URIs, Linked Data principles, RDF(S)/OWL, triples, etc.). These interfaces include geolocation mashups and faceted browsing, some of which will be detailed in Section 4. Hence, SemSLATES bridges a gap between Enterprise 2.0 and the Semantic Web in both directions (Fig. 1) by (1) providing a Semantic Web layer for enabling Linked Data on top of Enterprise 2.0 applications, and (2) using user-friendly Web 2.0 interfaces for browsing and querying complex RDF(S)/OWL graphs.

[9] http://sioc-project.org

[10] http://moat-project.org

3.2 Ontologies for Enterprise 2.0

As seen in the previous section, various layers of semantic annotations are required to enable the SemSLATES vision, each layer corresponding to a particular kind of ontologies.

With regards to models for representing users, social interactions and the content generated from these interactions, *i.e.* socio-structural metadata, our proposal relies on popular vocabularies used in the Social Semantic Web realm [7]. In particular, we focus on FOAF for representing user information and social networking and SIOC to represent the conversations and interactions happening in their related online communities. By using these models to describe uniformly content from different — and originally heterogeneous — applications, we enable a first common layer of semantics for Enterprise 2.0 ecosystems. Among others, the choice of these models has been motivated by:

- their wide adoption on the Web — and consequently their related community — , which has lead to notable user-feedback and improvements that the enterprise can benefit;
- a large number of tools and APIs available for managing related data, both for generating and consuming it;
- their simplicity, so that they can easily be enhanced and integrated with more specific models if required.

Regarding the ontologies required for modeling business data, they obviously depend on the domain(s) of interest discussed in the information system. It can be quite broad, ranging for simple description of companies to accurate representation of solar cell components. However, the SemSLATES approach focuses on reusing as far as possible existing and public ontologies, notably the ones proposed in the context Linking Open Data initiative[11], as described in [4], for two main reasons:

- first, as for the use of the previous models, enterprises can benefit from a large community feedback instead of building a new model from scratch, hence benefiting from earlier developments regarding these ontologies. In addition, in case they are extended (as we will discuss when presenting our case-study), these extensions can be published on the Web so that the enterprise providing it can benefit from feedback from other communities — and even other enterprises — using it;
- then, it provides means to reuse existing data available publicly on the Web and modeled with these ontologies. For example, using the GeoNames ontology[12] internally permits to reuse the million of entities provided openly in the GeoNames knowledge base[13], with facts such as coordinates, population, etc. We shall see later how this can be used to build low-cost semantic mashup, since data integration can be done in a straightforward way — as the same models

[11] http://linkeddata.org

[12] http://sws.geonames.org/

[13] http://geonames.org

are used internally and on the Web, this does not require any ontology or data alignment process.

Furthermore, existing enterprise ontologies can also be reused in this context, as well as taxonomies and thesauri (for instance translated to SKOS — Simple Knowledge and Organization Scheme [24]). That way, background information from the company can be reused in these Enterprise 2.0 settings , bridging the gap between traditional enterprise knowledge management and socially-enhanced information systems.

Finally, and to bridge the gap between these two layers, there is a need for models linking user-generated content to the various objects they are dealing with. Here, our approach relies on MOAT (combined with the Tag Ontology [25])[14], since it offers a vocabulary bridging the gap between free-tagging and semantic indexing. It aims at representing the meaning of tags through identifiers (URIs) of the objects they represent, these objects being modeled with the aforementioned ontologies. Using it, users can associate their tags to structured resource from the previous ontologies (and share these associations), hence solving the ambiguity and heterogeneity issues of tagging, as well as their lack of structure. Then, as we can see in Fig. 1, it enables a complete approach for providing Linked Data in Enterprise 2.0 environments, with a strong emphasis on the user aspect, while not neglecting the business domain.

3.3 Generating Semantic Annotations Through Software Add-ons

In order to generate the semantic annotations corresponding to the previous ontologies, add-ons must be provided to the original applications. As we make a distinction between different levels of ontologies — notably between ontologies for modelling socio-structural metadata and the ones aimed at modelling business data — we also rely on different methods for generating these annotations.

On the one hand, the creation of socio-structural annotations can be fully automated, by using services translating internal data structures or APIs to RDF data based on the previous models. Many exporters and APIs are already available to produce FOAF and SIOC data, and can be consequently used in those contexts[15]. Hence, this first layer of semantics can be provided without any additional user input, in a completely transparent way. We will see in the upcoming section how we enabled it in our context, generating RDF data from existing blogs, wikis and RSS feeds.

On the other hand, the process of creating annotations related to domain ontologies can be seen as a usual ontology population process. However, instead of using tools such as Protégé, our approach benefits from existing Web 2.0 applications and their associated social behaviours to create and maintain ontology instances. In particular, semantic wikis [40] are an appropriate technology as they

[14] Note that CommonTag can also be used here, see http://commontag.org/

[15] See for instance http://sioc-project.org/applications.

can be used to create and maintain ontology instances by using the wiki philosophy principles: openness, collaborative access, and versioning. Then, they enable collaborative management of structured knowledge bases, whereas traditional wikis enable the management of document-based repository.

Finally, regarding semantic tagging, one can benefit from existing MOAT applications. MOAT tools provide user-generated semantic indexing capabilities, by letting users associate their tags to the resources they represent (identified by their URIs). Thus, users can link tags and tagged content to the various resources created from the aforementioned semantic wikis. Moreover, MOAT features a collaborative architecture that enable these links between tags and resources to be shared and exchanged in the enterprise. In addition, frameworks such as FLOR (FoLksonomy Ontology enRichment [1]) may be used in combination with MOAT to automatically provide these mappings between tags and URIs, and hence make the process easier for end-users.

Combined together, these applications, extending the initial tools, enable a complete collaborative food-chain of semantic annotation in Enterprise 2.0 environments, where each step can be achieved by different users and communities:

- structured representation of objects (projects, technologies, etc.) is generated *via* semantic wikis;
- content discussing these objects is generated using other applications, such as weblogs;
- semantic tagging provides the glue between these two levels.

3.4 Deploying Additional Services

Finally, the next step of the SemSLATES vision consists in enabling new services that consume the data generated through the previous applications.

Indeed, the whole RDF(S)/OWL annotations produced using these tools form a single Linked Data graph, either *via* direct links between instances or through the use of shared ontologies.

However, that graph — in addition to being relatively complex because of the different representation layers that it involves — is highly distributed since it consists in different sub-graphs spread in the enterprise (since each tool generate a set of RDF documents corresponding to its annotations).

Our proposal relies on using a central RDF-store to aggregate and store this data, a store on top of which new applications can be provided.

This choice was mainly motivated by performance reasons (since response time of distributed querying are not acceptable in enterprise settings), and makes our architecture an hybrid approach between traditional middleware systems (which query original data sources *via* adaptors and re-compose the query results) and data warehouses.

However, using a central storage system also implies to maintain it up-to-date compared to the original services and the data they generate.

Based on the dynamic structure of the tools producing the annotations (as a consequence of their social interactions), we must ensure that there is no temporal gap between the time when data is published and when it can be used, *i.e.* when it is stored in the system.

To enable such synchronisation, SemSLATES uses a notification approach similar to the ping systems often used in the blogosphere (such as http://blo.gs), and that we also applied on the Web for RDF data with Ping The Semantic Web [5]. Each time some structured data is created, updated or removed in any of the original tool, a notification is sent from the tool to the RDF store, which immediately adds, updates or removes the related graph.

In addition, we rely on SPARUL (SPARQL/Update [36]), and its related HTTP bindings to provide an additional abstraction layer for data storage[16].

Consequently, interactions between services and the RDF store are achieved (i) on the one hand with SPARQL for querying data and (ii) on the other hand with SPARUL for updating and removing it, both *via* HTTP through the store endpoint. As a consequence, any RDF store supporting SPARQL and SPARUL *via* HTTP can be used in such architectures, offering a dual-abstraction layer where data storage services are completely independent from the other components.

4 Case-study: Enabling SemSLATES at EDF R&D

4.1 Background

Most of the information monitoring and sharing process at Électricité de France R&D used to be done by collecting information from Web sites using tools like WebSite-Watcher[17], capturing knowledge using Lotus Notes databases[18] and delivering information using traditional email processes. Mid-2005, the Athena project started with two main objectives. On the one hand, it aimed at optimising the aggregation and diffusion of information in the company, through innovative solutions. On the other hand, it focused on establishing new collaborative processes in the enterprise, particularly regarding information sharing and collaborative knowledge management between engineers and researchers. In that context, a first Enterprise 2.0 platform was deployed, providing (in chronological order):

- aggregated RSS feeds — enabling (i) information integration from external sources into the enterprise and (ii) open sharing of this information at the workplace;

[16] While SPARQL/Update is currently under standardisation process within the W3C, the initial SemSLATES approach was based on the former W3C SPARUL Member Submission — http://www.w3.org/Submission/2008/SUBM-SPARQL-Update-20080715/

[17] http://aignes.com

[18] http://www.ibm.com/software/fr/lotus

- blogs — letting users (i) react to any news from these RSS feeds and write new content, as well as (ii) interact each others through comments;
- wikis — enabling knowledge capture, especially to provide open, user-driven and consensual information, while blog mainly focus on items with a strong temporal emphasis (*e.g.* breaking news).

As mentioned in Section 2, we identified and analysed various issues regarding knowledge management in this particular context. We thus deployed the aforementioned SemSLATES methodology in that ecosystem, and we will now describe how its different steps have been achieved.

4.2 Extending Popular Ontologies

Our first requirement was to agree on a set of ontologies used in this particular SemSLATES implementation. While modelling socio-structural metadata is achieved using FOAF and SIOC, particular vocabularies were needed to address the business domain. In our context, our modelling needs mainly involved the representation of organisations, including information such as their location, partners and members, as well as the industrial domains they are involved in.

As we mentioned in the previous section, we relied on popular vocabularies such as FOAF, SKOS or GeoNames to build this representation layer. First, in order to model organisations, we extended FOAF through a lightweight FOAF extension, named FOAFplus, adding classes such as `foafplus:ResearchInstitute` or `foafplus:Company` and properties like `foafplus:acronym` to the FOAF Ontology. One of the reason we extended FOAF rather than using another existing model dedicated to persons and agents was to focus on a lightweight model that we could easily apprehend, extend and reuse, while at the same time conforming to particular ontology engineering best practices [28]. With regards to industrial domains, we relied on SKOS to represent and to organise them hierarchically. SKOS can indeed be used to represent that `d:SolarEnergy` is broader than `d:SolarCells` but narrower than `d:SustainableEnergy`. This hierarchy was also used in a role ontology [28] dedicated to modelling in which industrial domains, and regarding which kind of business (*e.g.* research, sales, etc.) were involved the previous organisations.

Overall, our aim was to focus on modular and lightweight ontologies [13] rather than implementing a single and huge model to cover all our needs, especially in order to reuse some components in other applications (as the aforementioned role ontology). However, combined together, they formed a complete ontology stack to cover our different needs regarding the modelling of business domains.

4.3 Automated SIOC-based Annotations

In order to automatically produce SIOC data from our existing applications, we designed different SIOC data exporters for our blog and wiki systems (both based on the Drupal SIOC exporter, that we co-developed and made publicly available[19]), as well as a service translating incoming RSS feeds into SIOC data. For each exporter, we relied on specific classes from the SIOC Types module[20], *e.g.* `sioct:BlogPost` to model blog posts and `sioct:WikiArticle` for wiki pages, as well as using `sioct:Comment` to model comments related to such posts (Listing 1[21]). In addition, we also used FOAF for modelling people's personal profile information (name, etc.). Moreover, while these exporters have been build for our particular purposes, we designed a PHP SIOC API[22] so that new plug-ins and exporters of that kind can be engineered with minimal effort.

Listing 1 Modelling a blog post and its reply using SIOC.

```
<http://athena.der.edf.fr/blog/104> a sioct:BlogPost ;
  sioc:has_creator <http://athena.der.edf.fr/user/3> ;
  dct:title ``Recent news about EDF" ;
  dct:created ``2009-08-03T22:50:32Z";
  dct:subject ``EDF" ;
  sioc:content ``Today, EDF announced [...]" ;
  sioc:num_replies ``1" .

<http://athena.der.edf.fr/blog/104#c1> a sioct:Comment ;
  sioc:reply_of <http://athena.der.edf.fr/blog/104> .
```

As soon as the exporters were online, every new content was automatically provided as RDF using the aforementioned models. Moreover, every content previously generated also became available as RDF, and been integrated in this Semantic Enterprise 2.0 ecosystem. Furthermore, this translation step was done completely transparently for the end-users. Thus, they kept their existing publishing habits and did not have any further action to take in order to enable this first layer of Linked Data in the enterprise.

4.4 Knowledge Capture Using UfoWiki

More than 80 wikis have been created during the lifetime of the Athena project. Valuable information is contained within, however, as we have seen, its reuse is a complex task due to the plain-text nature of the wikis. In order to generate struc-

[19] http://drupal.org/project/sioc

[20] http://rdfs.org/sioc/types

[21] Prefixes omitted.

[22] http://sioc-project.org/phpapi

tured and machine-readable data from these wikis, and to enable semantic annotations regarding business data, we focused on the use of semantic wikis to enable collaborative ontology population. Especially, and in order to provide such feature as an extension of our platform, we engineered a dedicated engine, named UfoWiki — Unifying Forms and Ontologies in a Wiki [29] [30] — based on our original wiki system. It enables the definition of form-based templates for wiki pages, mapped to classes and properties of underlying ontologies — in our case, the ontologies presented in the previous section. Forms are constructed in a back-end interface where administrators define widgets (such as “Geolocation”) mapped to particular properties (and classes) of the ontologies[23]. Moreover, these widgets can then be reused between different forms using a simple drag and drop interface. While we engineered our own system, in order to provide it as an extension of the original wiki engine, such form-based wiki interfaces are also used in systems such as the Semantic Forms extension for Semantic MediaWiki — `http://www.mediawiki.org/wiki/Extension:Semantic_Forms` —, the Project Halo — `http://semanticweb.org/wiki/Project_Halo` — or Kaukolu [17].

Using UfoWiki, users simply created and maintained instances by editing wiki pages and filling in forms that appeared in addition to the main textarea of each page. For example, instead of writing *“EDF is an organization located in France”*, users filled in a *Company* page template (mapped to our `foafplus:Company` class, subclass of `foaf:Group`) and a *Geolocation* field (mapped to the `geonames:locatedIn` property) so that the following RDF triples would be immediately created when saving the page (Listing 2). In addition, to enable the reuse of URIs between wiki pages, our system features a live auto-completion system (based on SPARQL queries), ensuring a correct interlinking of resources across wikis.

Listing 2 Modelling business data through UfoWiki.

```
athena:EDF rdf:type foafplus:Company ;
  rdfs:label ``Electricit\'{e} de France" ;
  foafplus:acronym ``EDF" ;
  geonames:locatedIn <http://sws.geonames.org/3017382/> .
```

Moreover, UfoWiki features a triggering system that queries the GeoNames web service for each *Geolocation* field in order to retrieve its URI — instead of creating a new identifier for each location. This can be seen in Listing 2, where the URI <`http://sws.geonames.org/3017382/`> identifies the city of Paris, capital of France, on GeoNames. While users are required to type in an exact location, *e.g. “Paris, France”*, we allow the reuse of external data in our system to provide advanced browsing features and semantic mashups, as we will describe later. This however has a drawback, since it implies that enterprises rely on public data that they cannot necessarily control and for which the quality of service is not always

[23] Note that for domain/range reasons, we were not able to automatically generate the forms, see details in [27].

ensured[24]. To that extent, alternatives could consider in hosting a replica of the required data internally, as for instance done in [16]. In addition, once again, this process could also focus on integrating existing and internal corporate ontologies or taxonomies (and related data) in order to interlink end-user contributions to legacy data from the enterprise.

In terms of statistics, we studied the evolution of one of these UfoWiki-enabled wikis, with 18 users participating and contributing to more than 300 instances during a six-month period. In addition, six users were interviewed and agreed that the additional complexity of filling in forms (rather than using a plain-text wiki interface) was relatively minor compared to the various advantages and features it provided, which we will describe in the next section.

4.5 Semantic Tagging Add-ons

While most of the generic MOAT clients[25] require users to enter the URIs of their tags' meaning(s) to enable semantic indexing when creating and tagging content, we enhanced this approach to make it as user friendly as possible — and do not confront our users to such technicalities. Firstly, users are never shown any URIs as the meanings of tags are suggested via their human-readable labels as soon as tagged content is saved in the system. Moreover, when a user links a particular tag to a resource, this mapping becomes her or his default choice for that particular relationship, making further annotations simpler. Furthermore, if no relevant meaning has been suggested, users can navigate (using a visual browser) through the taxonomy of classes and instances of our internal knowledge base to choose another meaning for their tag, once again without seeing any URI. This is also an innovative aspect of our approach: users create new ontology instances using semantic wikis, and then use these instances to define the meanings of their tags. In case no corresponding resource exists, users can create a new instance (while this step is generally dedicated to wikis as we have shown before). Furthermore, since these two steps can be achieved by different users, we enable a complete social process for instance management, tag meaning identification — and consequently semantic indexing. Finally, the relations between tags and URIs are shared in the corporate environment, so that one can benefit from mappings defined by others, providing an *architecture of participation* component to the semantic tagging approach.

Listing 3 represents the annotations related to the semantic indexing of a given blog post about EDF using MOAT. As we can see, it enhances the global interlinking between the different components of our architecture, linking together a blog post and ontological resources. Thus, by combining this information with the one generated through wikis (Listing 2) and using SIOC (Listing 1), we can identify that this particular blog post is about a company based in France. Therefore, we provided a

[24] In addition, confidentiality issues have to be considered, as some information filters out from the enterprise.

[25] http://moat-project.org/clients

complete Linked Data food-chain in the enterprise, using independent components providing distinct but interlinked annotations, as they reuse common URIs to identify the resources they deal with. In terms of statistics, 1,176 tags and about 17,000 instances of `sioc:Post` (and related subclasses) have been linked to 715 different URIs of resources, these links being represented via MOAT, showing a user willingness to do this manual interlinking step, in spite of the additional efforts it requires. In addition, note that our goal was to keep the initial tagging feature intact in order to let user express their "desire lines"[26] when tagging content, not forcing them to use a particular term to annotate it.

Listing 3 Example of semantically enhanced tagged data with MOAT.

```
<http://athena.der.edf.fr/blog/104> a tag:RestrictedTagging
  tag:taggedResource <http://athena.der.edf.fr/blog/104>;
  foaf:maker <http://athena.der.edf.fr/user/3> ;
  tag:associatedTag <http://athena.der.edf.fr/tags/EDF>;
  moat:tagMeaning <http://athena.der.edf.fr/data/EDF> .

<http://athena.der.edf.fr/tags/EDF> a moat:Tag ;
  moat:name ``EDF'' .
```

4.6 Additional Features of the Platform

As we have exposed when describing the SemSLATES architecture, all these services interact with a central RDF-store on top of which new services are deployed. In our context, we relied on 3store[27] and implemented a SPARQL/Update HTTP endpoint, in order to provide that abstraction layer between it and the other services. We will now describe some of the new applications that we engineered and deployed to enhance the initial information system.

4.6.1 Enhancing the Wiki Features

In order to solve the issues of knowledge capture and re-use that we mentioned in Section 2.2, we designed a processor for semantic macros in UfoWiki, inspired by Semantic MediaWiki inline queries [20]. Semantic macros allow to embed the results of SPARQL queries in wiki pages — without requiring users to face the complexity of such queries (especially when combining the different layers of semantic annotations). Macros are defined by wiki administrators and are mapped to SPARQL query patterns and (X)HTML templates, so that they can be integrated in

26 http://www.adaptivepath.com/publications/essays/archives/000361.php

27 http://threestore.org

wiki pages using a simple grammar syntax. For example, `[onto|members]` will be translated into a SPARQL query that will retrieve all the members of the organisation currently browsed, these members being then displayed in the wiki page.

These macros offer a way to integrate information from different wiki pages and are thus used to augment knowledge discovery. Moreover, they also take advantage of the socio-structural metadata layer and of the semantic indexing capabilities of our proposal. As each wiki page is related to a particular instance, some macros are used to include a list of the latest 10 posts (as defined by `sioct:BlogPost`) that are linked to this instance (via MOAT), once again reusing available Linked Data from the enterprise to enhance user-experience and information integration. That way, it provides users with a direct integration of news and blog posts in wiki pages, so that they can instantaneously browse not only static information but also identify recent news, a novel feature which was particularly appreciated.

4.6.2 Semantic Search

In addition to this macro system, we also developed and deployed a dedicated semantic search engine which uses the whole data available in the RDF store (ontologies and annotations) to answer users' queries [32]. As for content generation, this engine bridges the gap between syntax and semantics [14], *i.e.* it provide means to search information about relevant resources (in particular instances of classes of our domain ontologies), and not only documents.

When users search for a particular keyword, a SPARQL query identifies the related instances, using regular expressions based on the tags and their meanings (via MOAT) as well as using the `rdfs:label` (and subproperties) values of the instances. If various instances are identified, the system asks the user to select the relevant one. For example, the system asks the user to choose between "Association des Maires de France" (association), "France" (country) or "Électricité de France" (company) if a user searches for the string "France", so that the search is then restricted to the relevant resource only. Once this resource has been identified, the engine lists all information about it, *i.e.* (1) the corresponding tags, (2) the main wiki page, (3) the related wiki pages (*i.e.* pages about instance(s) linked to the current one) and (4) every content item linked to the current resource, thanks to MOAT and an automated RSS indexing process running in the background. This way, the system solves information fragmentation issues as it provides users with a single entry point to access any content regarding a particular object, identified from several sources and initially distributed in the enterprise, avoiding the need to switch between different systems as in the past.

In order to bridge that semantic gap when searching for information, the use of MOAT showed a clear advantage. We indeed identified that 205 resources were linked to more than one tag; in fact, 39 were linked to more than four different tags. Consequently, it implies that four different tag-based queries would have been necessary to identify all the related content, while a single one is sufficient using this search engine, a feature that was also acknowledged by our users.

4.6.3 Semantic Mashups

Furthermore, in addition to this semantic search engine, we enabled advanced browsing interfaces and semantic mashups. In particular, we provided a faceted browsing interface using Exhibit[28] to navigate through the various organisations created using UfoWiki. The novelty of this approach is in the reuse of RDF data from GeoNames to provide a semantic mashup combining internal and external data sources, thanks to the trigger feature in UfoWiki that we explained previously. We can therefore see in Fig. 2 that information from the enterprise (company names and domains) is combined with GeoNames data (coordinates of their location), enabling such advanced navigation features. While this was relatively straightforward to implement, it was also praised by users, notably as it offers a visual representation of their plain-text content, also giving them incentives to publish more data.

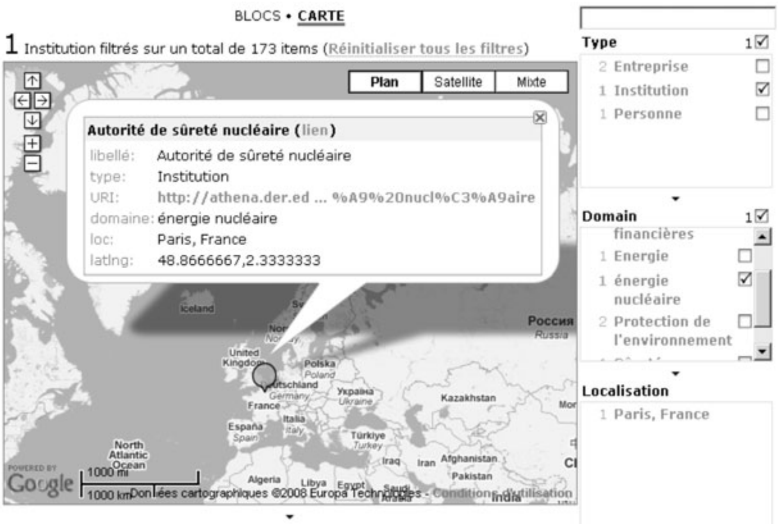

Fig. 2 A semantic mashup and faceted browsing interface for Enterprise 2.0 data, combining internal data and public RDF data from the Web.

We believe that these semantic mashups can be a significant part of the future of Enterprise 2.0 applications and greatly demonstrates the interest of the Linking Open Data initiative for organisations. Similar to how RSS allows companies to benefit from public information (news feeds, blogs, etc.), reusing RDF data brings knowledge about different topics into the enterprise for zero cost (since no data nor ontology alignment is required) — not only for public services as described by [19], but also within intranets as in our case. Furthermore, we can also imagine mashups combining, as said previously, Enterprise 2.0 data with existing legacy data from the enterprise.

[28] http://simile.mit.edu/wiki/Exhibit/

5 Conclusion

In this chapter, and based on our work at Électricité de France R&D[29] [26], we presented the SemSLATES approach, extending the original SLATES definition of Enterprise 2.0 by enabling a social semantic middleware architecture on top of existing Enterprise 2.0 ecosystems [27], using Semantic Web and Linked Data technologies. We especially showed how to combine different layers of semantics to provide this additional stack of structured and semantic information on top of social information spaces, without requiring a complete redesign of the information system, but through simple add-ons and plug-ins, and then bringing novel application to end-users, solving most issues of genuine Enterprise 2.0 systems. Then, to quote François-Xavier Testard-Vaillant, formerly senior adviser for corporate collective intelligence at EDF R&D: *"The Semantic Web is one of the tools we have experienced that creates bridges between communities and it does the job provided that it remains almost invisible thanks to a smart and user friendly interface. I do think that the Semantic Web will be a means to encourage our researchers to share more and more knowledge and that it will be easier and easier to use. We do need this"* [26].

In addition, while we focused only on the integration of data from Web-based services, we believe that new data sources could be added to enhance the user experience and information in such Enterprise 2.0 contexts. On the one hand, new internal information could be considered, which could consist in (1) information from the desktop, especially considering Semantic Desktop applications [3], which could integrate calendar of address book information in such services for personalised search, and (2) sensor-based information and data from mobile services, which could also provide some background context when searching for information (*e.g.* geo-locating answers to particular queries). On the other hand, more data from the Linking Open Data cloud could be integrated in these ecosystems, enhancing the initial values of the corporate tools by reusing openly available data to enhance user experience, offering new kind of semantic mashups. Moreover, it could also provide means to integrate different Enterprise 2.0 ecosystems together, providing a global ecosystem of networked knowledge, encompassing data from both the Web and the enterprise [33].

Furthermore, while the work described here was done in the context of a R&D project, many tools and ontologies used, designed and researched during that project are now stable and mature enough to be used in a broader enterprise context and to minimise the associated risks: scalable triple-stores are available on the market, various APIs can be used to deal with RDF(S)/OWL data, ontologies such as SIOC or SKOS got a broader update and hence benefit from large toolkits, query languages are more mature, etc.

Overall, we have thus showed that existing Enterprise 2.0 systems could greatly benefit from Semantic Web and Linked Data technologies, without requiring fundamental changes both in the architectures or in user's habits. We shall however

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[29] http://edf.fr

remind that, since a main component of the SemSLATES approach is the user itself — as it requires users voluntary sharing their data to enable the semantic annotations and the Linked Data layer — it can be a success only if the Enterprise 2.0 philosophy itself has been acknowledged, understood and appreciated in the enterprise.

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