ComVantage: Mobile Enterprise Collaboration Reference Framework and Enablers for Future Internet Information Interoperability

Angelika Salmen[1], Tobias Münch[1], Steffen Buzin[1], Jan Hladik[1], Werner Altmann[2], Conny Weber[3], Dimitris Karagiannis[4], Robert Buchmann[4], Jens Ziegler[5], Johannes Pfeffer[5], Markus Graube[5], Manuel Carnerero[6], Oscar López[6], Mikel Uriarte[6], Patricia Órtiz[7], and Oscar Lázaro[7]

[1] SAP Research, SAP AG, Germany
[2] Kölsch and Altmann Software Management and Consulting GmbH, Germany
[3] ISN - Innovation Service Network GmbH, Austria
[4] University of Wien, Austria
[5] Technische Universitt Dresden, Chair for Process Control Systems Engineering, Germany
[6] NEXTEL S.A, Spain
[7] Innovalia Association, Spain

{angelika.salmen,tobias.muench,steffen.buzin,jan.hladik}@sap.com, {werner.altmann}@koelsch-altmann.de, {conny.weber}@innovation.at, {dk,rbuchmann}@dke.univie.ac.at, {jens.ziegler,johannes.pfeffer,markus.graube}@tu-dresden.de, {mcarnerero,olopez,muriarte}@nextel.es, {olazaro,portiz}@innovalia.org

Abstract. Future Internet Networked Enterprise Systems demand enhanced collaboration and mobility support. FI technologies are fundamental for increased service differentiation and cost optimisation in manufacturing environments. However, such ICT-based capabilities are not easy to introduce, in particular to SMEs, due to high costs and complexity. To progress in more effective development of value added services based on Web 2.0 principles within a mobile enterprise collaboration context, the complexity of collaboration in terms of information management needs to be leveraged from the end-users. Linked Data (LD) provides a universal and lightweight approach for the collaboration network. However, the elaboration of collaborative business processes based on LD still needs to be properly formulated for FI systems. The aim of this paper is to present a reference architecture for mobile enterprise collaboration based on LD interoperability. Moreover, security, semantic data lifting, business process modelling interoperability and mobile app orchestration enablers are presented to facilitate trustful and effective inter-organisational collaboration.

Keywords: Mobile enterprise collaboration, Future Internet, Linked Data, Industrial Applications, Multi-domain Access Control, Interoperability.

A. Galis and A. Gavras (Eds.): FIA 2013, LNCS 7858, pp. 220–232, 2013.

1 IT Challenges for Collaboration

The manufacturing industry provides over 30 Million jobs throughout the EU as well as employment in various directly associated industries. The industry has further been globalised for the last years and is still expected to increase their collaboration rate. While by 2011 the percentage was about 40%, business outcomes that will depend on parties outside one enterprises control will reach 60% by 2015 [1]. Thus, new requirements emerge for Future Internet Networked Enterprise Systems to meet the manufacturing and service industry demands.

ICT is a key factor for competitive advantage and growth of manufacturing industries due to its impact on productivity and innovation (cf. [2], [3], and [4]. A primary strategic role of ICT in the manufacturing industry is facilitating the collaboration among various organisations involved in industrial supply chains, enabling the efficient flow of information about procurement, inventory, production, delivery, etc. The strategic role of Future Internet technologies for manufacturing industries and supply chain management is highlighted by the fact that two Phase II Use Cases of the FI-PPP; *i.e. cSpace, FITMAN*, deal with specific enablers that will leverage enhanced collaboration processes. ICT in general and Future Internet technologies in particular facilitate the ability to introduce "mass customisation" capabilities, which allow individual end-customers to design and order a product that is uniquely tailored to their preferences. *Cost optimisation* (consequence of improved information flow) and *differentiation* (a consequence of mass customisation) based on ICT capabilities are responsible for the ability of manufacturers to sustain their competitive advantage in contemporary markets.

However, such ICT-based capabilities are not easy to introduce, in particular to SMEs [5], as they involve a high level of cost and complexity. Until now business process optimisation has been focused on centrally organised systems, as business software integrates own core competencies and relations to external partners and their expertise within a closed infrastructure. Although being secure and providing entire control, existing systems are less flexible or dynamic, because of the significant cost of introducing change to existing intra- and inter-organisational processes. Also co-ordination and communication with the partner network is cost intense. Improving the competitiveness of the European industry and striving for future leadership requires innovative approaches that enable lean and agile inter-organisational collaboration. Linked Data [6] in particular provides a universal and easy accessible interface and thus meets the requirements of a lightweight approach for the collaboration network. The provision and **interlinking of data** in the web, being readable for men as well as machines via Linked Data, has proven successful in the public sector. Yet, the elaboration of collaborative business processes based on Linked Data as an add-on to existing business and engineering software for industrial contexts needs to be properly formulated and validated in the context of Future Internet systems.

The EU project ComVantage [18] is elaborating a **product-centric mobile collaboration space** for inter-organisational users including end-customers based on Web 2.0 technologies. ComVantage addresses major challenges comprising the architecture of Future Internet Networked Enterprise Systems [7] facilitating secure multi-domain information access for the Web of Linked Data, coupling of legacy information systems, and provisioning of intuitive and easy to use mobile applications to meet the requirements of the production manufacturing scenarios. The ComVantage **reference architecture** meets the challenge of handling the complexity of heterogeneous data sources [8], while providing lean integration to legacy systems. It provides models and tools to interlink and exploit information on an inter-organisational level, and supports a unified orchestration of and communication between the various technology enablers. One major enabler is **multi-domain secure information access**, which deals with the challenge of handling the complex partner network and provide controlled access to private linked data sources based on authorised user roles, tasks, and multiple devices. To enable scalability of the complex network as well as allow for ad-hoc collaboration, the decision making takes place in a decentralised manner [9]. In addition to the secure access model, the Linked Data approach needs to reflect the underlying **business process models**. Business Process Models are partner specific in the collaboration network and may be based on various BPM languages which also requires a unified communication between these different languages. Therefore, the inter-organisational orchestration of the collaborative workflows needs to be mapped via Linked Data. Finally, ComVantage enablers also deal with **collaboration via mobile devices** to support flexible and location independent applications at the production shop-floor, as well as lightweight approaches suitable especially for small and micro-companies. Moreover, ComVantage enabler aims to transfer well-proved user experiences of single purpose mobile apps towards complex collaboration networks, where the challenge is to orchestrate these mobile apps according to the underlying business workflow and generate easy to use mobile user interfaces.

The chapter is organised as follows. First, ComVantage application areas driving the specification of the technology enablers in the context of the Future Internet are introduced. Next, the reference architecture designed for mobile enterprise collaboration is presented. Then, Section 4 to Section 7, introduce the specific technology enablers proposed by ComVantage in the area of data adaptation, business process modelling, mobile development frameworks and multi-domain linked data access control. Finally, the main conclusions are presented.

2 ComVantage Application Areas in a Nutshell

ComVantage should leverage heterogeneous data interoperability technology enablers for enterprise mobile collaboration. This core idea is illustrated by two exemplary use cases to visualise the ComVantage business value proposition. 1) **Mobile Maintenance** is addressing a temporary, project-based collaboration including SMEs in the automation industry. It faces the challenge to provide a unified interface that handles the technological complexity and vast heterogeneity of data to provide it for the collaboration hub and to exchange information on an inter-organisational level. 2) The second use case is **Customer-oriented Production**. The specific challenge here is to enable the integration of micro-companies and end-customers into the collaboration network. Infrastructure demands on micro-companies to introduce lightweight mobile applications is too large. Furthermore, end-customers are hardly integrated into the production process which hinders creativity and customer satisfaction to a certain extent.

2.1 Mobile Maintenance Scenario

Currently maintenance service companies are spending too much effort and money in finding out which type of error occurred and or which type of spare part and in the end which type of machine expert is needed to repair a special type of machine, that might be world wide installed for different customers. In classical and standard situation maintenance is done in corrective and/or even better in preventive scenarios to avoid too long time slots where the machines are really not available. This situation can be better addressed if information managed by different companies; e.g. machine sensor information, component evaluation tests, maintenance operations performed, etc, could be easily connected and exploited for maintenance purposes. The focus of the ComVantage Mobile Maintenance System is on innovation in the Mobile Maintenance Area, especially in predicting of impending machine defects.

2.2 The Customer-Oriented Production Scenario

A big challenge faced in sectors such as the fashion industry is that design and production processes still are disintegrated with end-customers. No communication channel exists that allows direct interaction with the customer on production level, while at the same time the request for individual products is increasing. As complex and individual products are key for European competitive advantage the gap between companies and their customers is still too large. Potentials such as open innovation or crowdsourcing lie dormant. The objective of this scenario is to refine along the example of Dresscode21, a company offering personalized business shirts, the establishment of the ComVantage prototype for a mobile web shop, i.e. the web shop will focus on mobile devices for customers as well as for the production stakeholders. A further objective of this application scenario is to enhance the competitiveness of SMEs by leveraging a more seamless information exchange among the different suppliers involved within a design and production process. The challenge lies in customers being able to access style recommendation services, shirts designed by the crowd and product information via social media platforms. In parallel, the challenge lies in supporting a highly flexible collaboration space with all interested stakeholders capable of supporting Dresscode21's service, i.e. providing personalized shirts.

3 ComVantage Reference Architecture

As presented in Section 2, to progress in a more effective development of value added services based on Web 2.0 principles within a mobile enterprise collaboration context, demands that the complexity of collaboration in terms of information management is leveraged from the end-users. This vision requires a collaboration network reference architecture to be driven by four main goals:

1. Enterprise data of the collaboration network members remain within existing legacy systems and in the responsibility of the information owner.
2. Enterprise data is leveraged in inter-organizational contexts in a harmonized manner to ease the development and use of collaboration tools.
3. Enterprise data is interlinked among collaboration network members and connected to public data sources to leverage social web added-value.
4. Enterprise and public data are enriched with business process context and embedded into single purpose mobile apps orchestrated to cover complex workflows.

According to the first goal, data is organized in encapsulated domains. Each domain owner enforces his own access control based on local policies. Local access control policies are defined regarding a shared role model that is valid within the whole collaboration network. Furthermore each domain owner specifies which information will be shared with other domains in the collaboration network. Thus, the domain owner keeps full control about his data despite sharing it with external partners. The described features are provided by the Domain Access Server which acts as a single point of access for each domain (see Fig. 1) and offers a HTTP interface for simple GET requests or more complex SPARQL [10] queries to client applications. Usually a domain is represented by an enterprise or a project-based association of enterprises in a collaboration network.

The second goal is addressed by the application of semantic technologies which allow for an abstraction from heterogeneous data source technologies and data models including deviating terminologies. Within each domain a semantic data model of the enterprise environment is created as ontology and is used for the data harmonization within the Data Integration Layer. An adapter for each legacy system will transform syntactic data to RDF [11] and map it to the semantic data model. Client applications are able to access specific information without awareness of concrete data sources or handling of heterogeneous data models. The clients are only aware of the endpoint addresses of each Domain Access Server and the corresponding semantic data model.

The third goal is achieved by utilizing the Linked Data design principles [6]. Linked Data resembles the idea of hyperlinks on the level of machine readable data in order to establish a web of interlinked resources. Foundational aspects to Linked Data are the use of dereferenceable HTTP URIs to identify resources over the web and the use of triple-based notations (RDF) to express semantic statements. The aforementioned semantic data model of each domain is used to derive Linked Data from traditionally syntactic legacy systems within specialized adapters. In order to ease the creation and the retrieval of links across organizational boundaries as well as to public data sources, a mapping between the semantic data models of all connected domains within the collaboration network is provided.

The fourth goal is realized by the use of comprehensive business process models at design time of client applications. ComVantage focuses on mobile applications and implements their main success factors. The most relevant factor is the use of application with very narrow scope and functionality to improve user experience. These single-purpose apps usually cover the processing of one task. In order to support complex workflows within an enterprise, ComVantage offers an advanced app orchestration mechanism to execute individual applications regarding the current workflow step. The dependencies between individual workflow steps, the required resources like view definitions and data invariants are defined in business process models which are used to generate mobile applications with the model-driven development approach. The finally deployed apps contain all the navigation logic and computing tasks of one workflow step as well as the semantic SPARQL queries for requesting information from each domain.

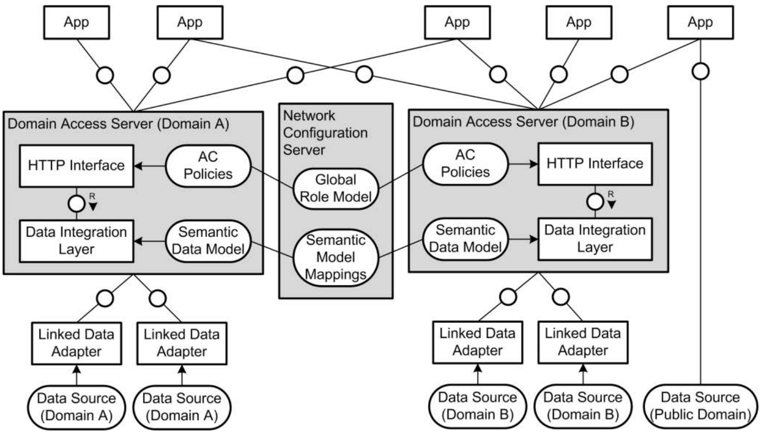

Fig. 1. ComVantage high-level architecture of the collaboration network prototypes

4 Security Model for Linked Data Access Control

Collaboration between different organizations can only be successful if partners can trust each other and be ensured that the information they share remain secure and only authorized users will access the data exposed in the collaboration network. However, within a collaboration environment decision-making is profoundly different from centrally coordinated collaboration. Relying on forming a single domain of trust is no real guarantee that other partners will behave as agreed in the future. Thus, it is essential to define a security approach enabling **policy negotiation, establishment, monitoring and enforcement** for a multi-domain access to linked data sources. In order to guarantee that the information remains private to authorized members only, a dynamic access control model is essential, which supports the most complex combinations of company-based and user-role based rights for access control.

ComVantage security model for decentralised access management to linked data sources is based on the definition of controls for different elements: **(1) Linked Data Units (LDU)**.They are constructed attaching data identifiers and access control policies to data objects. **(2) Linked Data Sets (LDS)**. Aggregate LDU within a domain and specific access control policies. **(3) Linked Data Networks (LDN)**: They are created across domains based on agreements among companies to collaborate in the execution of a particular task-project. Linked Data Units are accessed on the specific enterprise LDN based on the user-role and workflow step being performed.

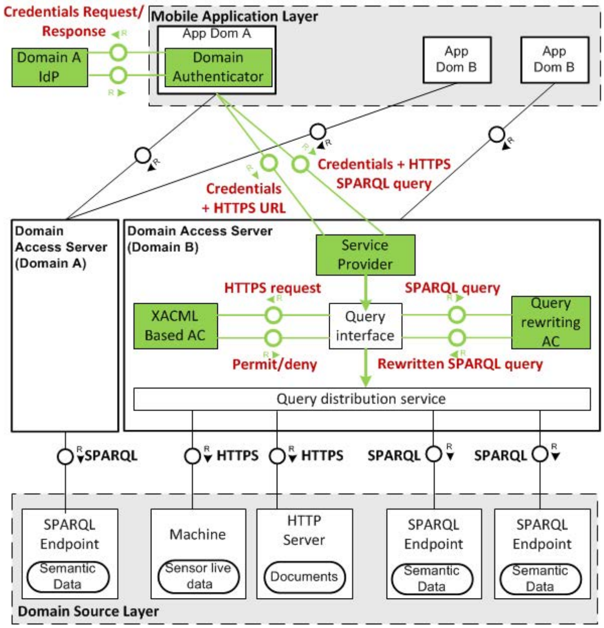

Fig. 2. ComVantage security concept

Access to information takes place at two levels. On one hand, in the domain access server through generic interfaces a request for information is performed. On the other hand, in the data adapters, through specific data interfaces, data is invoked. The security concept should therefore ensure that the queries in the system are compliant with the security policies and that the LDS published by each company and shared through specific LDN, remain accessible only to those partners. ComVantage, as depicted by Fig. 2, proposes a multi-tiered security approach to enhanced role-based multi-domain access control for linked data with two controls: **(1) Domain Access Server Control** is in charge of the first access control level, authorizing only authenticated users who present a security token as well as required personal attributes and role to be granted. At this level SPARQL query rewriting is performed, augmenting the original query with specific security checks to be taken in account by each of the final Endpoint enforcers in the second level. **(2) Data Layer Control** is located at a lower level controlling the executing of the queries on the data sources. This security level, is organised by means of an intelligent structuring of information, which enables the implementation of delegated access controls based on ad-hoc yet traceable information sharing.

5 Semantic Data Lifting

Section 3 highlighted the importance of offering a universal, easily accessible interface for various kinds of information that is compliant with legacy systems. Therefore, ComVantage enablers should facilitate integration of data without semantic information contained in legacy systems with the semantic data model. This functionality, also referred to as *semantic lifting*, is performed by the Linked Data adapters shown in Figure 1. These adapters have to be as unique as the data sources they connect with and their underlying data models. In the ComVantage application areas, these sources range from standard database management systems to highly specific proprietary data management middleware. This demonstrates the versatility of ComVantage Linked Data based approach for integration and collaboration.

5.1 Linked Data Adapter for Databases

The first linked data adapter is driven by the customer-oriented production use case and enhances a standard SQL database system for. In order to semantically lift this data and make it available for collaboration, it is necessary to transform the database entities (like customers, orders, or products) into RDF entities referenced by a unique URI; to assign these objects to their respective RDFS classes; and to transform each line of a table into a set of RDF triples, where columns containing foreign keys are represented by object properties (i.e. they connect two URIs), whereas columns containing literal values are mapped to data properties (i.e. they connect a URI with a literal). This transformation is done using the D2RQ platform [12]. D2RQ reads data from a relational database, converts it into RDF using a set of rules (which logically contain the semantics of the database) and exports this data in RDF or HTML format. It also offers a SPARQL endpoint for queries. Figure 3 shows the RDF graph resulting from this transformation. Here, the oval shapes stand for RDF classes, the diamonds for individuals, and the rectangles for literal values, like text and numbers. Some of the relations between these entities come from the *Friend of a Friend (FOAF)*[1] and vCard[2] ontologies. The benefit of this translation is that instead of the proprietary data model from the database, vocabularies are used some of which are global standards. Even for proprietary vocabularies, a user can dereference

[1] `http://www.foaf-project.org`
[2] `http://www.w3.org/2006/vcard/ns`

the URIs in order to find out the meaning of the term. The knowledge contained implicitly in the database structure is made explicit and available to application developers.

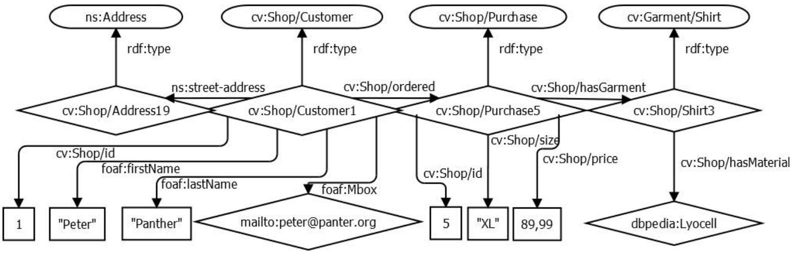

Fig. 3. Semantically lifted database content

5.2 Linked Data Adapter for Real-Time Sensor Data Middleware

The second LD adapter is driven by the RST[3] mobile maintenance application area. This one has more sophisticated demands for its LD integration concept since the maintenance use cases require access to *live* sensor data. The update intervals of these sensor readings are often in the magnitude of milliseconds; thus pushing this data into a triple store is not practical. So a component that transforms the sensor readings into RDF on-the-fly is needed.

In order to access live data, the mobile maintenance application, which runs on a mobile device, accesses the LD server. The server returns a semantic description of the relevant machines, which also contains references (URIs) of the sensor readings. If such a link is dereferenced, the LD server contacts the LD adapter to obtain the current reading. The LD adapter accesses the middleware controller using RST's *Gamma* protocol. The return value is transformed into RDF and reported back to the LD server, so that it can be displayed by the mobile maintenance application.

6 The ComVantage Modelling Framework

Section 3 has highlighted the relevance of business process modelling in the technological context given by Linked Data and mobile app support. This has to be supported by modelling methods able to bridge the business vision with its technological requirements. For this, the ComVantage modelling method has been designed, based on a meta-modelling framework described in [13]. The framework defines a modelling method through its three building blocks: **(a) A modelling language** specifying modelling constructs, their syntax and semantics (grouped in model types addressing specific problems see Figure 4); **(b) A modelling**

[3] http://www.rst-automation.de

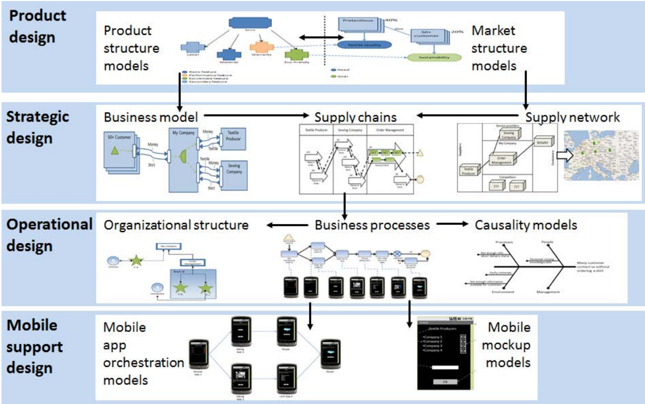

Fig. 4. The ComVantage modelling method stack, version 1.0 [18-D3.1.1]

procedure comprising steps and guidelines to be followed towards the modelling goals; **(c) Mechanisms and algorithms** specifying functionality to be implemented in modelling tools (such as model transformation, visualization, querying and simulation).

A first version of the modelling method specification is shown in Figure 4 for a layered stack of its model types. It has a wider scope than the modelling requirements suggested by Section 3, as it targets the generic context of supply chain management, supporting a modelling procedure comprising the following high level steps: **(1) Product structure / feature design** with a mapping on needs and goals captured from existing market structure research; **(2)** Product features suggest roles required by the production process, which are the basis for **strategic designs**: the business model (according to the e3 value language [14]), the enterprise-level supply network and the product-level supply chain (expressed according to standard frameworks like SCOR [15] [16] or VRM [17]); **(3) At operational level**, business processes can be modelled and mapped on resources of various types: human, hardware, information resources and mobile apps. **(4)** Further on, **mobile app orchestration and abstract design**s can be modelled to express mobile IT support requirements. This layer is involved in the model-driven approach from Section 3 and it relies on: (a) an RDF vocabulary for exporting diagrammatic models in a linked data format; (b) graph rewriting rules for deriving app orchestration from the business process models. (c) a process stepping mechanism to support employee training regarding execution and app support for business processes.

7 Intuitive and Trustful Mobile Collaboration

ComVantage strives to bridge the gap between current state of the art mobile apps and industrial environments. In contrast to complex monolithic applications, apps are affordable, small and fast to develop. However, in the professional area, there are predefined tasks and workflows, which are usually diverse, variable and complex. To accomplish these tasks, apps have to provide proven usability in the industrial context of use and a high level of security and trust to the users. Furthermore, whole sets of apps may be necessary in order to accomplish a complex task showing the need for orchestration of these apps with one another according to the defined workflows within this task. For these reasons, we argue that a common, model-based and tool-supported orchestration of all necessary apps is more feasible in the industrial context than the existing concept of individual app selection and management by each user [19].

ComVantage has developed an innovative concept called *Mobile App Orchestration* for building applications which are able to leverage inter-organizational collaboration spaces for complex workflows. To achieve this goal the concept relies on a three step process (see Figure 5): **(1)** Select, **(2)** Adapt, **(3)** Manage. *Select and Adapt* steps are executed at design time while *Manage*reaches into run time. During selection, apps are selected from a repository (*App Pool*) according to the workflow that is supported. The App Pool contains *Generic Apps* which support a certain task type, e.g. list browsing, diagram analysis but need to be adapted to the use context before they satisfy the needs for industrial usage.

Then the apps are *adapted* to the context of use, taking the data model, ontologies and access rights into account. Basic adaptation is achieved by parameterizing the app's data acquisition (e.g. a SPARQL template), setting a style sheet and choosing app parameters. Selected and adapted apps are installed during the *manage* step on a mobile device with the navigation design derived from the workflow model. On the device a run-time component loads the navigation design and manages inter app communication, switching and data access.

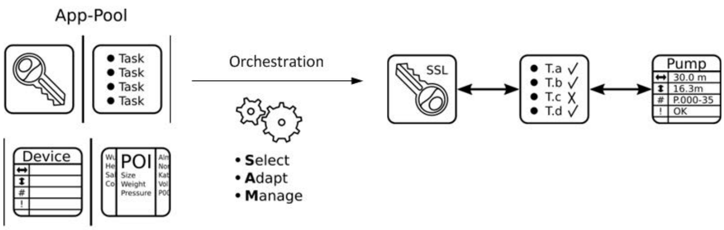

Fig. 5. ComVantage Mobile App Orchestration Concept

8 Conclusions

This chapter has presented the ComVantage reference architecture to meet business and IT challenges for efficient mobile enterprise collaboration in customer-oriented production and mobile maintenance scenarios. The set of collaboration use cases have demonstrated the need for a solution that can facilitate a secure task-driven exchange of product-centric information among different enterprises for the mobile worker. To support such innovative applications, a semantically lifted linked data solution has been proposed that is also supported by a multi-tier linked data access control concept for multi-domain operation. The chapter discussed the benefits of enhanced modelling frameworks for dynamic business collaboration and introduced the concept of Mobile App Orchestration for trustful and intuitive introduction of mobile apps into industrial environments.

Future research directions beyond the ComVantage project should focus on more effective policy management frameworks for efficient View management that derive into optimized inferring processes and data view maintenance. Moreover modelling tools may be turned into knowledge acquisition tools capable of exposing captured knowledge as Linked Data structures. In this direction, metamodels exported as Linked Data can be used to bridge the gap betwwen prescriptive metamodelling and descriptive ontology engineering. Finally, along with the increasing exploitation, more and more Generic Apps will become available for orchestration, which calls for sophisticated tools for App Pool management.

References

1. Gartner Says the World of Work Will Witness 10 Changes During the Next 10 Years (August 4, 2010), http://www.gartner.com/it/page.jsp?id=1416513
2. OECD. Policy Responses to the Economic Crisis: Investing in Innovation for Long-Term Growth. OECD report (June 2009), http://www.oecd.org/dataoecd/59/45/42983414.pdf
3. EU 2020, http://ec.europa.eu/eu2020/index_en.html
4. Digital Agenda (2010), http://ec.europa.eu/information_social/digital-agenda/index_en.html
5. Lazaro, O.: Future Internet and SMEs, FInES Task Force, Brussels (October 12, 2012), http://www.fines-cluster.eu
6. Berners-Lee, T.: Linked Data (2006), http://www.w3.org/DesignIssues/LinkedData.html
7. Angelucci, D., Missikoff, M., Taglino, F.: Future Internet Enterprise Systems: A Flexible Architectural Approach for Innovation. In: Domingue, J., et al. (eds.) Future Internet Assembly. LNCS, vol. 6656, pp. 407–418. Springer, Heidelberg (2011)
8. Pettenati, M.C., Ciofi, L., Pirri, F., Giuli, D.: Towards a RESTful Architecture for Managing a Global Distributed Interlinked Data-Content-Information Space. In: Domingue, J., et al. (eds.) Future Internet Assembly. LNCS, vol. 6656, pp. 81–90. Springer, Heidelberg (2011)
9. Bezzi, M., Trabelsi, S.: Data Usage Control in the Future Internet Cloud. In: Domingue, J., et al. (eds.) Future Internet Assembly. LNCS, vol. 6656, pp. 223–231. Springer, Heidelberg (2011)
10. Prud'hommeaux, E., Seaborne, A.: SPARQL Query Language for RDF (2008), http://www.w3.org/TR/rdf-sparql-query

11. Klyne, G., Carrol, J.: Resource Description Framework (RDF): Concepts and Abstract Syntax (2004), http://www.w3.org/TR/rdf-concepts
12. D2RQ homepage, http://d2rq.org
13. Karagiannis, D., Kühn, H.: Metamodelling platforms. In: Bauknecht, K., Tjoa, A.M., Quirchmayr, G. (eds.) EC-Web 2002. LNCS, vol. 2455, p. 182. Springer, Heidelberg (2002)
14. Gordijn, J., Akkermans, H.: E3-value: Design and Evaluation of e-Business Models. IEEE Intelligent Systems 16(4), 11–17 (2001)
15. Bolstorff, P., et al.: Supply Chain Excellence. AMACOM, New York (2007)
16. The Supply Chain Council, http://supply-chain.org/
17. The Value Reference Model, http://www.value-chain.org/en/cms/?1960
18. The ComVantage project - public deliverables page, http://www.comvantage.eu/results-publications/public-deriverables/
19. Ziegler, J., et al.: Beyond App-Chaining: Mobile App Orchestration for Efficient Model Driven Software Generation. In: 17th IEEE International Conference on Emerging Technologies and Factory Automation (in Press)