An Innovative Virtual Enterprise Approach to Agile Micro and SME-Based Collaboration Networks

Tobias Münch[1], Robert Buchmann[2], Johannes Pfeffer[4], Patricia Ortiz[5],
Conny Christl[3], Jan Hladik[1], Jens Ziegler[4], Oscar Lazaro[5],
Dimitris Karagiannis[2], and Leon Urbas[4]

[1] SAP Research, SAP AG, 76131 Karlsruhe, Germany
{Tobias.Muench,Jan.Hladik}@sap.com
[2] University of Vienna, Faculty of Computer Science, Knowledge Engineering Dpt.,
1210 Vienna, Austria
{rbuchmann,dk}@dke.univie.ac.at
[3] ISN – Innovation Service Network d.o.o, 2250 Ptuj, Slovenia
Conny.Weber@innovation.at
[4] TU Dresden, Chair of Process Control Systems Engineering,
Institute of Automation, 01062 Dresden, Germany
{Johannes.Pfeffer,Jens.Ziegler,Leon.Urbas}@tu-dresden.de
[5] Innovalia Association, 48008 Bilbao, Spain
{olazaro,portiz}@innovalia.org

Abstract. This paper demonstrates a lightweight and highly decentralized collaboration infrastructure approach for virtual enterprises and describes its added-value in the customer-oriented production domain. First, we will describe challenges and key requirements of an exemplary application scenario. Second, we are going to present the reference architecture and will explain the designs of enabling key concepts. Finally we highlight major improvements to the selected domain and the impact in economic, competition and social terms.

Keywords: Virtual enterprises, semantic data interoperability, process interoperability, business process modelling, mobile application orchestration.

1 Challenges of Micro Companies in a Virtual Enterprise

Regarding the Small Business Act for Europe [1], small and micro companies are important actors in all business fields across Europe with growing tendency. Small and medium-sized businesses (SME's) cover 37 per cent of added-value to the business economy. Micro companies with headcounts less than 10 employees cover 21 per cent of the added value to the business economy [2]. From a quantitative perspective, micro, small and medium enterprises represent 99.8 per cent of all firms all over Europe.

In the European textile sector small and micro companies faced massive changes both in retail and manufacturing due to saturated markets and their weak integration with partners. However, winners in the market have abandoned the traditional retail

model for the so called vertical integrated approach. Its success is twofold: On the one hand side it is the transparency and control of the whole product value chain from the design, the production up to the retail of products. On the other hand side it is a deep understanding of their customers' needs and its integration into design and production processes as well as offering customized products.

Along the use case in the textile industry we present our vision of how micro companies can compete in a global market by transforming from isolated individual companies towards an integrated, agile virtual enterprise. A virtual enterprise is based on a temporary alliance of several businesses [3] and takes advantage of a market opportunity. It does not have own resources but consists of the resources of the individual partners.

In our visionary scenario, customers have high degrees of product personalization. Within the network, designer, producers, and end-customers communicate, collaborate and exchange relevant information in order to control a common and highly agile product value chain without high transaction costs. Ordering and production processes will be managed completely decentralized. The following six high-level requirements need to be addressed: 1) Virtuality (distributed and decentralized infrastructure) 2) Mobility (compatibility with commercial mobile devices) 3) Usability (intuitive tools for workers) 4) Flexibility (configuration of generic components) 5) Collaboration (interorganisational workflows) 6) Security (securing local data sets).

2   Architecture of a Virtual Enterprise

The ComVantage project has the goal to develop a reference architecture as well as a working prototype of a distributed collaboration infrastructure for virtual enterprises. In the following, the key characteristics are described.

2.1   Decentralized Approach

Even in a heterogeneous and distributed collaboration environment, companies want to continue running their legacy systems and want to keep full control of their valuable enterprise data. Our fully decentralized approach proposes a separation into *Domains* where a domain can be operated by an individual partner or can be shared among a couple of partners. This characteristic provides full scalability and satisfies the different needs of large and micro enterprises. Referring to the setup outlined in Figure 1, the webshop owner as major partner (partner A) of the collaboration network is running his dedicated IT-infrastructure (domain A). The tailor shop and the embroidery as micro companies (partner B1 and B2) are using a shared IT-infrastructure (domain B) which saves them efforts and costs related with running and maintaining their own one.
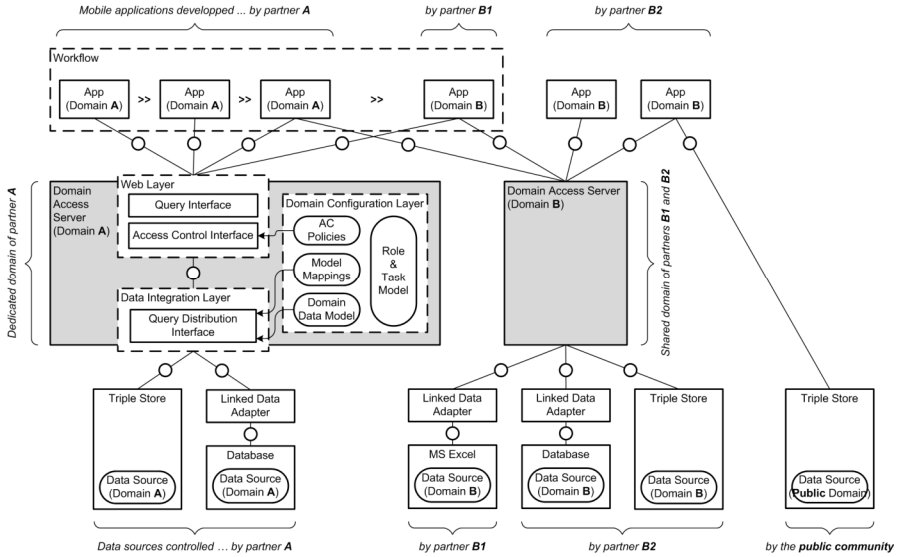
Fig. 1. Reference architecture for data- and process-interoperability in a virtual enterprise

2.2 Data Modelling

Major design-time activities in setting up a decentralized collaboration network are: First, creation of roles and tasks to define the subject of collaboration (*Role & Task Model*). This model is used to define local access rights on data sources. Second, the creation of local access control policies (*AC Policies*) guarantee full control about restricted and shared information within local data sources to each domain owner. Third, ontologies (*Domain Data Model*) to describe the data model of each domain are needed to enable the semantic data harmonization. A specification of the used methodology and the developed metamodels can be found in [4] as well as in the public deliverables D4.1.1-3 [5]. Unfortunately, ontology engineering is not easily applicable to micro companies. We envision a process that explicitly omits the complexity of developing ontologies from scratch for each partner. Micro companies should be able to join a collaboration network by simply adapting existing ontologies. In ComVantage we developed the tool *OntoSketch* that facilitates ontology engineering by offering support for ontology extension based on existing ontologies from collaboration partners and public communities. It allows the user to import existing ontologies, browse and filter their contents, and extend them with new concepts. The UI provides assistance to make ontology engineering also applicable to non-expert users.

2.3 Single Point of Access

Major difficulties of interorganisational collaboration consist in heterogeneous data models (structuring and naming of entities) and incompatible interfaces based on different technologies. In ComVantage we decided to use semantic data harmonization based on RDF, Linked Data and ontologies. RDF [6] is used as uniform data format

based on the Linked Data design principles [7]. Within each domain of the collaboration network, a single point of access is provided by the *Domain Access Server* (Figure 1). The *Web Layer* of the server exposes a uniform interface for applications based on SPARQL [8] and provides an interface for enforcing access control policies. The *Data Integration Layer* is responsible for distributing requests to the connected data sources of the domain and merges all results to a combined result set. The *Domain Configuration Layer* provides components for a domain specific configuration of the Domain Access Server.

2.4   Integration of Legacy Systems at Run-Time without Modifications

Integration of heterogeneous data sources is crucial to data harmonization. The ComVantage approach is based on *Linked Data adapters* that will perform a mapping of syntactic data to RDF. The adapters are provided as generic components which will be configured with the Domain Data Model of the actual domain in order to connect to a specific data source. Using adapters offers the advantage of integrating legacy systems without modifications. Hence, the ComVantage approach can be used on top of an existing IT infrastructure and in parallel to already existing business applications. The adapters are provided for several technologies which are most common in micro-company environments. The Linked Data adapter for databases is based on the open source project D2RQ [9]. The adapter translates SPARQL queries to SQL and returns results based on a domain-specific mapping. While the mapping is defined at design-time, the content is lifted to RDF on demand at run-time which avoids the problem of keeping redundant data in sync. Since the database doesn't contain the semantic information that is required for this transformation, it is provided in a mapping file. Furthermore, adapters for Excel spreadsheets [10] and machine middleware systems are provided [4].

2.5   Access Control on Individual Enterprise Data Assets

Interorganisational collaboration relies on trust between partners and the fact that information from heterogeneous nature is accessible to authorized members only. An access control model is required that supports decentralized decision-making and that enables policy negotiation, establishment, management, monitoring and enforcement for a multi-domain access to Linked Data sources. Additionally, the mechanism should be simple enough to be applicable for micro companies. We propose an authentication process based on SAML [18]. Identity federation and security credentials interchange is performed in the first place and, afterwards, a multi-tiered authorization process takes place to provide multi-domain access control for Linked Data at two levels: (1) Rewriting of SPARQL queries by adding control checks related to the requesters user role. (2) Structuring of information in views for each data source to physically protect data that is not visible for a specific user role.

2.6   Modelling of Workflows and Orchestration of Applications

Additionally to the described data modelling approach we provide a workflow modelling workbench oriented towards business stakeholders within the design-time dimension of the architecture. A hybrid modelling method has been designed under

the framework presented in [11] to capture collaboration and mobile app requirements on multiple levels of abstraction (a specification is available as a series of public deliverables at [5]). The modelling procedure recommends that each business process is first designed in a business view (with a "one responsible/activity" granularity), then extended to a technical view (with a "one required app/activity" granularity, to support the orchestration). We do not employ standard BPMN [12] tools for several reasons: a) the business process modelling language is only a fragment of a method which must integrate, on a metamodelling level, additional domain-specific semantics and abstraction layers captured in auxiliary linked models; b) the models are to be exported in a metamodel-dependent custom-made Linked Data schema, currently not supported by BPMN tools; c) practitioners reclaim a simplification of business process modelling [13], thus we try to avoid syntactical bloating and, notation-wise, the IT-inspired graphical representations. A comparison of collaboration patterns relying on swimlane-based control flows to BPMN is highlighted in Figure 2.
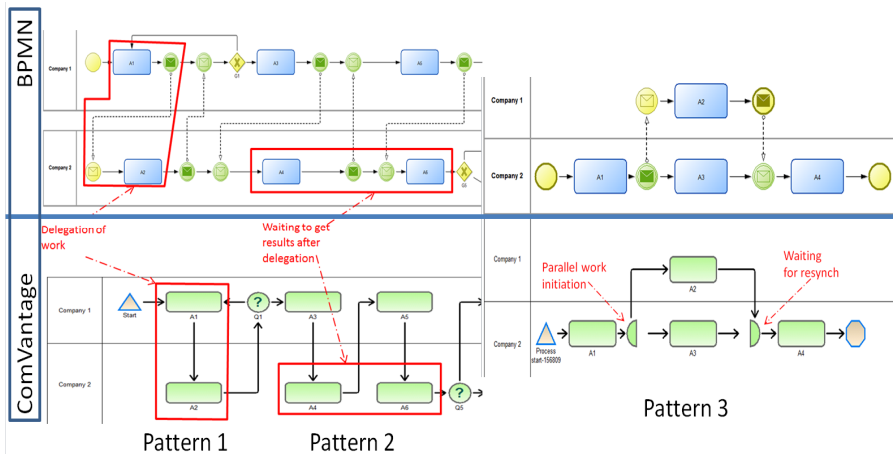
**Fig. 2.** Mapping of BPMN patterns (top) on the ComVantage approach (bottom)

Pattern1: Delegation or transfer of control. BPMN relies on explicit "throw and catch" messaging events between two activities. Our approach implies it with "subsequent" arrows shifting control between different roles (swimlanes). By convention, any activity initiating a cross-swimlane arrow can be considered a "notifying activity". Pattern2: Waiting to get results after delegation/transfer. BPMN relies on a sequence of activities on the same swimlane that is interrupted by throwing and catching messages. Our approach implies this with a lack of subsequent arrows continuing on the same swimlane. Pattern3: Delegation/transfer followed by parallel work. BPMN relies again on messaging to initiate a parallel flow in the partner company and to resynchronize with its results after the parallel work is finished. Our approach uses a parallelity split to distribute work between the two swimlanes, and a corresponding join to indicate where work must be synched back together.

Additional semantics are given by navigable links to related models (of other types), and can be explicitly serialized through an export mechanism (as N-quads [14]) to enable querying outside the modelling tool. For purposes of mobile app

development, the most relevant links are the one from activities (in business process models) to roles and app features (in a resource pool model), for example:

:A1 a :Activity; :lane :Company1; :mobilesupport :Notifying_feature.
:Arrow1 :from :A1; :to :A2.

The first part will assure that the assignment between activities and swimlanes is not only a visual indication, but also an RDF relation that can be queried in order to detect the discussed patterns for further processing (for example, to assign mobile app skeletons based on them). The second part captures a link between the activity and an app feature required to support it, while the last part captures the process flow.
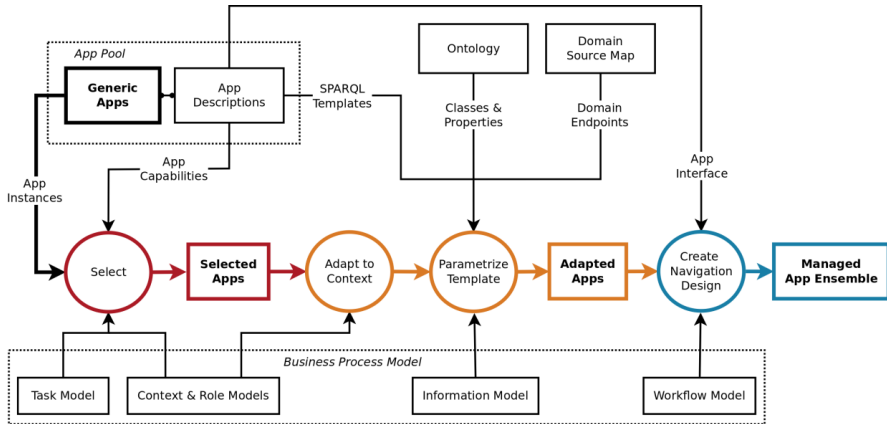
Fig. 3. The App Orchestration Process of the Industrial App Framework (see [17]). The three main steps (Select, Adapt, Manage) rely on various models as input. An App-Pool contains apps and formal descriptions that allow automatic selection. The end product is an App Ensemble that can be deployed on mobile devices and supports a specific workflow.

In ComVantage, such serializations of collaborative business process models are input for an *App Orchestration Process* [15] that is offered in the *Industrial App Framework* (IAF) (see Figure 3). Its goal is to simplify the usage of apps for mobile support of workflows in virtual enterprises. Existing models (e.g. business processes) are used to select the most appropriate apps from a pool, adapt them to the context of use, connect to data sources and create a navigation design that resembles the modelled business process [15]. The effort for supporting a workflow on mobile devices is much lower than with state of the art technology. Existing apps with proven usability can be reused and adapted to context [16, 17], missing apps are created using app templates and style guides (developed in ComVantage), and existing models can be used to drive the orchestration process.

3   Conclusion

ComVantage offers a collaboration infrastructure that facilitates data and process interoperability within virtual enterprises. Compared to related approaches in the field of semantic data harmonization like SemaPlorer [19], Aletheia [20] and Information

Manifold [21], ComVantage combines interoperability capabilities with a decentralized architecture which is crucial for the application within virtual enterprises. However, our approach is based on a lightweight infrastructure and is therefore lacking advanced semantic reasoning capabilities.

In this paper we highlighted the impact of our approach on small and micro companies that have a strong need for collaboration in order to gain a critical mass on core competencies and resources for competing with the global market. These companies need to implement lean and agile business processes to react on dynamic market opportunities. ComVantage responds to this by offering a modelling workbench for business processes and a model driven development approach for mobile apps taking into account the agility of workflows supported by the App Orchestration Concept. Furthermore, small and micro companies have a need for non-expert support for specific design-time tasks. We offer a couple of templates, guidelines and tools for facilitating tasks like ontology engineering and app development. Finally, the lightweight infrastructure of ComVantage simplifies the introduction of software tools to technology unaware environments as usually being found in small and micro companies and enables a complete end-to-end transparency among the whole production and supply chain of a product. Tracking and monitoring of used resources and related costs of a specific product will be much easier across the whole production and supply chain.

Regarding the social impact, ComVantage enables small and micro companies to join virtual enterprises on low investments but high strategic benefits. Micro companies who are suffering losses because of the global competition can benefit from the realization of the open virtual enterprise vision. This allows for example a designer, or a small tailor shop to apply for open production orders. Transferring the success factors of vertical integrated companies to a virtual enterprise consisting of a network of micro companies awakes further chance potential for European micro companies both manufacturers and retailers.

The concepts shown in this paper are result of the first year of the ComVantage project. Currently first prototypes are in development and a comprehensive business value evaluation will be conducted in the third year.

References

1. Small Business Act for Europe (2012),
   http://ec.europa.eu/governance/better_regulation/documents/
   minimizing_burden_sme_EN.pdf (retreived)
2. SBA Fact Sheet Germany (2012),
   http://ec.europa.eu/enterprise/policies/sme/
   facts-figures-analysis/performance-review/files/countries-
   sheets/2012/germany_en.pdf (retreived)
3. Barnett, W., Presley, A., Johnson, M., Liles, D.: An Architecture for the Virtual Enterprise. In: The Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, San Antonio (1994)

4. Hladik, J., Christl, C., Graube, M., Haferkorn, F., Pfeffer, J., Urbas, L., Willfort, R.: Improving Industrial Collaboration with Linked Data and OWL. In: Proceeding of: 10th OWL: Experiences and Directions Workshop, OWLED 2013 (2013)
5. The EU Project ComVantage, http://www.comvantage.eu
6. World Wide Web Consortium. Resource Description Framework, RDF (2004), http://www.w3.org/RDF/ (retreived)
7. Bizer, C., Heath, T., Berners-Lee, T.: Linked data - the story so far. International Journal on Semantic Web and Information Systems 5(3), 1–22 (2009)
8. World Wide Web Consortium. SPARQL Query Language for RDF (2008), http://www.w3.org/TR/rdf-sparql-query/ (retreived)
9. D2RQ, Accessing Relational Databases as Virtual RDF Graphs (2006), http://d2rq.org (retreived)
10. XLWrap, Spreadsheet to RDF (2009), http://xlwrap.sourceforge.net (retreived)
11. 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)
12. OMG, The BPMN standard official page, http://www.bpmn.org/
13. Burlton, R.: Perspectives on Process Modeling (2009), http://www.bptrends.com/publicationfiles/ 07-09-COL-POV-Perspectives%20on%20Process%20Modeling- Burlton-cap%20_1_%20RB%20Final.pdf (retreived)
14. Bizer, C., Cyganiak, R.: The TriG syntax, http://wifo5-03.informatik.uni- mannheim.de/bizer/trig/
15. Ziegler, J., Graube, M., Pfeffer, J., Urbas, L.: Beyond App-Chaining - Mobile App Orchestration for Efficient Model Driven Software Generation. In: Proceedings of the 17th IEEE Int. Conference on Emerging Technologies and Factory Automation ETFA (2012) (in print)
16. Pfeffer, J., Graube, M., Urbas, L.: Browsing Reversible Neighborhood Relations in Linked Data on Mobile Devices. In: Benavente-Peces, C., Ali, F., Filipe, J. (eds.) Proceedings of the 2nd International Conference on Pervasive Embedded Computing and Communication Systems (PECCS 2012), pp. S.150–S.155. SciTePress (2012)
17. Urbas, L., Pfeffer, J., Ziegler, J.: iLD-Apps: Usable Mobile Access to Linked Data Clouds at the Shop Floor. In: Proceeedings of Workshop on Visual Interfaces to the Social and Semantic Web (VISSW 2011), CEUR-WS.org Proceedings, Palo Alto, California, US, February 13, vol. 694 (2011)
18. Online community for the Security Assertion Markup Language (SAML) OASIS Standard (2013), http://saml.xml.org/ (retreived)
19. Schenk, S., Saathoof, C., Baumesberger, A., Jochum, F., Kleinen, A., Staab, S., Scherp, A.: SemaPlorer – Interactive Semantic Exploration of Data and Media based on a Federated Cloud Infrastructure. In: Semantic Web Challenge, Int. Semantic Web Conference (2008)
20. Aletheia – Semantic Federation of Product information, http://www.aletheia-projekt.de/
21. Kirk, T., Levy, A.Y., Sagiv, Y., Srivastava, D.: The Information Manifold. In: Proceedings of the AAAI 1995 Spring Symp, on Information Gathering from Heterogeneous, Distributed Environments, pp. 85–91 (1995)