Cross-enterprise Process Orchestration – Framework for Collaborative Process Automation

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Abstract. New forms of cooperation like collaborative business scenarios require a deep but flexible integration of enterprises. To manage Business Process Automation across such networks existing concepts for integration need to be adapted and extended. In this paper a framework is presented, how cross-enterprise processes can be planned, implemented and controlled. The framework is based on the differentiation of global knowledge within the network and local knowledge of a participating company. In order to support the inter-enterprise interaction open platforms, e.g. orchestrated web services, have to be implemented. Orchestration secures the semantic content of the process-flow.

1 Innovation through Collaborative Business

The growing importance of cooperation is a result of globalization in combination with the loosing of political borders and technological changes caused by the Internet [1], [2]. Thus, enterprises have to react on the raised innovation pressure and are often forced to participate in trade on a global scale. Due to the resulting overcoming of regional limitations there is a need for resources that they cannot meet alone [3]. This leads to the creation of national and international cooperations, not only in the vertical interaction relations, but also during the collaborative production of goods and services with complementary core competence partners.

The borderless enterprise has been the subject of scientific discussion for some years [4], and the collaborative production of goods and services has been established as a crucial factor in the consciousness of economic entities. The opening of the organizations borders is no longer regarded as a necessary evil, but rather as a chance with strategic importance [5]. The additional effort caused by the network has to be overcompensated by the added-value. Enterprises have to build up new forms of cooperation characterized by a flexible and low-cost feasibility in order to be permanently successful on largely saturated markets.

Current approaches that address solutions to specific problems of flexibly interacting organisations are summarized under the term “Business Integration”; the field of investigation is referred to as “Collaborative Business (C-Business)” [6]. While the technological implementation on the one hand and the business model life-cycle on the other hand have been already intensively researched, too little consideration is given to the interconnecting business management concepts. A rethinking from the

Adam O., Hofer A. and Zang S. (2004).
Cross-enterprise Process Orchestration – Framework for Collaborative Process Automation.
In *Proceedings of the 1st International Workshop on Computer Supported Activity Coordination*, pages 185-197
DOI: 10.5220/0002667201850197

pure technology-driven implementation or profit-driven business model discussion to an integrated view that spans from the conceptual level to the system blueprint is needed. On the conceptual view business processes have proven to be the ideal design item in conjunction with the use of graphical methods. These methods can then be transformed into IT-based specifications. With the use of web services they enable Business Process Automation, i.e. the automatic negotiation of process interfaces.

In this paper this approach is expanded to the Framework for Collaborative Process Automation. The elaboration and implementation of such a concept is the subject of the research project ArKoS, sponsored by the German Federal Ministry of Education and Research (BMBF), that is introduced in the last section.

2 From Middleware to Collaborative Business

Up until now integration attempts aligned with technological necessities. Thus different middleware concepts and solutions were developed over the last years. Beginning with the simple Remote Procedure Call (RPC) or Remote Database Access, over Message Oriented Middleware and Transaction Processing Monitors, up to more recent concepts, such as Object Request Brokers (ORBs) or shared components [7]. Middleware however is used basically only for integration at data level; functions that enable further integration levels as object or process integration are missing [8]. „Enterprise Application Integration“ (EAI) provides an approach that goes beyond the pure technical connection of information systems. The different systems – both internal applications and of external business partners – are linked by a uniform integration platform. Therefore only one interface is required to connect the systems to the EAI-system as opposed to a large number of point-to-point connections. The system actively transports data from one application to the other according to the process flow and converts documents into the respectively needed format.

However, EAI still lacks another conceptual superstructure by means of which an intercompany collaboration can be planned and implemented. Therefore more recent approaches, such as Collaborative Business (C-Business) and E-Collaboration, expand the EAI idea into business management concepts and methods. C-Business describes the Internet-based interlinked collaboration of all participants in an added value network – from the raw material supplier to the end-consumer [9]. It allows a comprehensive information exchange not only between employees but also between departments and even between enterprises and encourages creative cooperations at all levels. As first case-studies show, the increase in added value is out of proportion to the amount of participants in the added value network. Unlike former concepts, as e.g. E-Procurement, which focused only on small parts of the value chain, E-Collaboration incorporates all stages of added value and business processes. Measures for Business Integration incorporate all relevant business partners into the system; by doing so they become part of the entire collaborative process [10].

For a detailed and systematic analysis and redesign of interorganizational processes, enterprises need a methodological framework that offers support at the business concept level up to their implementation into IT-systems. The appropriate graphic representation of these contents is of great importance in order to support the exchange of ideas and the reconciliation of interests between the different recipients

(management, departments and IT-department). Finding consent and decision-making between the different stakeholders is considerably facilitated by a general methodology; it encompasses not only the common conception of a collaborative business process but also the system-side implementation in an existing IT application landscape. Besides, today a lot of workflow-aware application systems are used in mission-critical environments, e.g. as an extension of ERP-systems. Thus the main challenge concerning technology is the open implementation and interoperability of these process-sensitive applications to integrate preceding and following process steps dynamically. The consecutive level of integration is called orchestration, i.e. the dynamic connection of autonomous process entities [11].

Loosely coupled component-based systems increasingly replace monolithic solutions, as e.g. ERP-applications [12]. However, as long as widely-recognized content-related and technical standards are missing, the use of component architectures is limited. To achieve a truly dynamic integration and interoperability these standards have to be consolidated in a framework to ensure a common procedure within the business network. For this purpose a proposal is to be developed by use of the framework for collaborative process automation.

3 Framework for Collaborative Process Automation

Compared to traditional processes, the complexity of enterprises spanning business processes rises considerably as a result of the numerous possibilities of interaction as well as the strategic, structural and corporate cultural differences between the partners. Coordinating the business partners turns out to be more difficult, especially because of the differing objectives and the lack of inherent organisational arrangements and behaviour guidelines as they exist within an enterprise [13]. The allocation of performances and resources of the business partners, the determination of responsibilities for material and financial exchange relationships, as well as the information and data exchange over interfaces have to be planned, arranged and "lived" together. Thus the demands on Business Process Management (BPM) increase.

Existing BPM methods and phase models are used as a foundation in the presented framework, which had to be adapted to the specifications of collaborative scenarios. Especially because of its completeness of vision and its proven practicability, both in the scientific and the economic context, the "ARIS House" [14] is accepted as a generic framework for business process management and serves as a basis for further considerations. The ARIS House describes a business process, assigning equal importance to the questions of organization, functionality and the required documentation. First, it isolates these questions for separate treatment, in order to reduce the complexity of the description field, but then all the relationships are restored using the Control View introduced for this purpose.

Additional basic principles for the derivation of the framework come from the examination of enterprise networks that have already been extensively analysed regarding their development, maintenance and dissolution. Thus life cycle models and phase models that are motivated from an organisational point of view have been developed [15].

Below, relevant aspects of C-Business management are represented in a three-tier framework that is connected through control loops, following the concept of business process excellence of Scheer [16], which consists of a model to track a complete life-cycle model of business process management, including modelling, real-time control and monitoring of business processes. The first layer of the "Framework for Collaborative Process Automation" focuses on the collaboration strategy. In the centre of the second layer, the "C-Business Process Engineering", there are design, optimisation and controlling of both enterprise spanning and internal processes. The third layer, "C-Business Execution", deals with the (operational) implementation of business processes in value-added networks as well as their support through information and communication technologies. The structure of the layer model is clarified in figure 1.

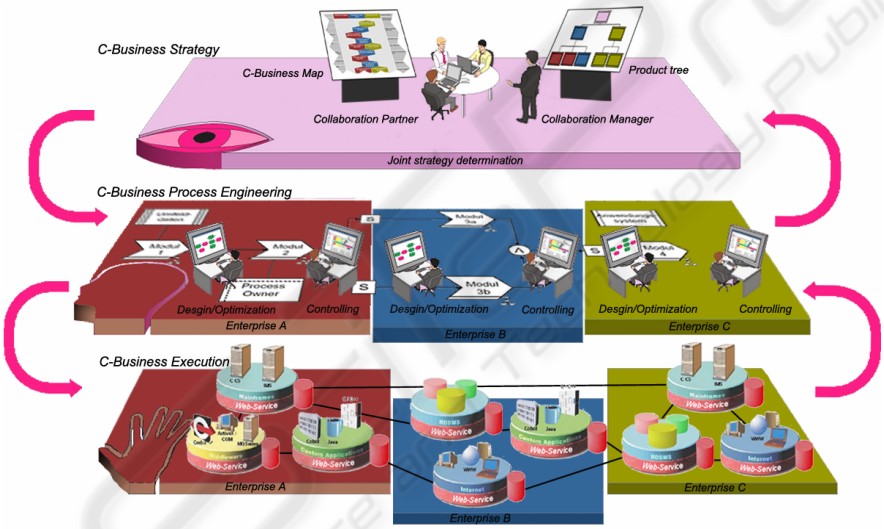

Fig. 1. Framework for Collaborative Process Automation

3.1 C-Business Strategy

Before using the framework there is an awareness of one or more enterprises that they can profit by collaboration with complementary core competence partners. Afterwards, in the formation phase, mostly referred to initiation and agreement of the enterprise network, the collaboration partners are determined by the shared goals of the collaboration and the aspired win-win situation of all partners. In this paper we assume that a set of potential network participants is given. The decision if and with which enterprises out of the basic set a C-Business scenario should be implemented is taken by every single enterprise individually and rationally; for this reason it depends highly on the expected economical profit of the individual partner. In the next step, the joint aims of the collaboration have to be defined as synthesis of the individual aims.

Assuming that the aim of the cooperation is a collaborative service production, graphic methods, like product models, are used in this stage for the determination of a common service bundle. They simplify and put the often implicit objectives into concrete terms. In addition to the characteristic features of a service or a product over its entire life-cycle, the organizational units participating in the service production are contained in a product model [17]. By means of product trees enterprises can conceal detailed service descriptions in an internal view that puts special focus on the organizational aspects of the product offered by the partners. In an external view they just provide the information required for the configuration of the common service bundle in form of product bundle models [18].

Enterprise spanning business processes are not planned in detail at the strategic level but designed as concentrated, high-level process modules. Thus, they combine the public knowledge about the collaborative processes that is shared by all participants. Business process models for collaborative scenarios at the strategic level merely no longer act on the assumption of a chronological view of the process, but more on a role-based process model to discover new value-added potentials. C-Business scenario-diagrams that are used e. g. by SAP Ltd. for the description of my-SAP.com collaboration scenarios (cf. figure 2), aim at the representation of the cooperation of different enterprises and participants by means of a simple to understand method and the documentation of the value-added potentials resulting from it [19]. The high-level processes are shown as hexagons in figure 2. The responsibility for each process step, indicated by swim-lanes, is of central importance to the determination of the scenario. This method is integrated into the ARIS concept and combined with methods of (classical) business process and data modelling used at the C-Business Process Engineering layer. This enables the generation of public and enterprise-internal views and levels of detail for management, process owner and IT-experts out of a C-Business model.

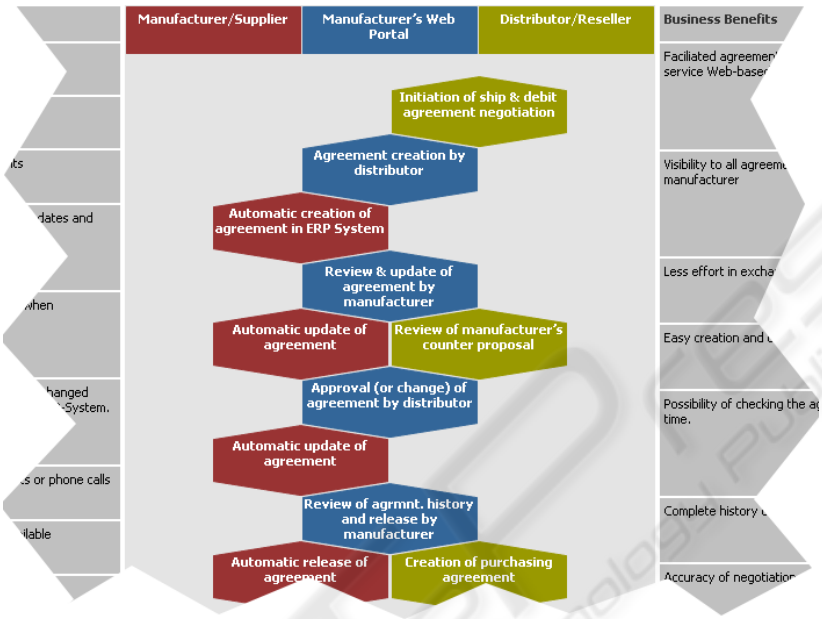

Fig. 2. Example of a C-Business Scenario

The question about the core competences in the enterprises is directly associated with the question which processes remain in the enterprise and which are supposed to be assigned to partner enterprises or collaboratively operated [20]. This decision again has direct effects on the IT-systems used, e.g. whether a portal is supposed to be implemented or the participation in an electronic marketplace is sought. C-Business strategic and technical problems cannot be considered independently from each other, therefore the IT-architecture is already initialised.

After the basic parameters of the collaboration are determined the procedures and the interactions are planned in more detail at the engineering layer.

3.2 C-Business Process Engineering

Having completed the strategy finding, in the next step the local (private) processes of each partner are adapted and the processes regarding the collaboration (global or public processes) are generated as an aggregation of all internal views of the network partners. The business processes will be designed by using reference models based on best practice and theoretical considerations. Like design patterns that show a generic solution of the network architecture on a technical basis reference models are used to show possible solutions for a process description on the conceptual level.

As described above, the framework is based on the ARIS House and divides it into a vertical axis of global knowledge of all collaboration partners and a horizontal axis of local knowledge of the single participants (cf. figure 3). The organisation view and the output view are global knowledge because a goal-oriented collaboration is impossible without them.

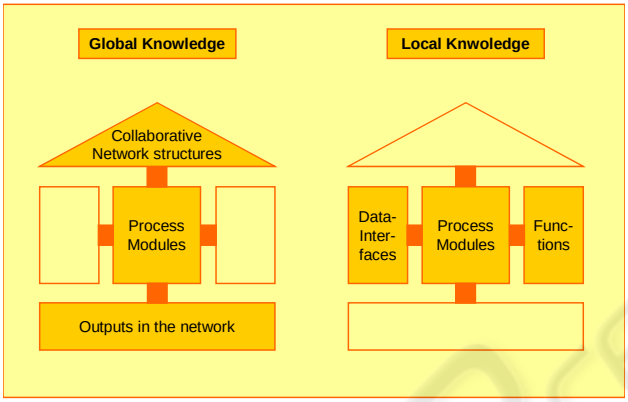

Fig. 3. Global and local knowledge in innovation networks

Global and local knowledge merge gradually in the step-by-step development of C-Business process engineering. Following this distinction between global and local knowledge, a language is needed for the exchange of these knowledge fragments. Because the necessary detail functions and data schemes of the respective enterprise are determined in the data and the function view, these are treated from a micro perspective. They are characterized by an intensive internal interdependence, whereas externally a standardized encapsulation has to be provided. Interfaces of the data and function views to other network participants become visible in the process view in form of attribute correlations to process modules and concern the technological field of the cooperation during the realisation much more intensely than the conceptual one.

Each partner considers their part in the inter-enterprise process. Starting with process modelling and optimisation over process controlling up to implementation, the processes involved are aligned with the requirements of the collaborative scenario agreed on at the strategic level. Each party models its own internal processes. The event-driven process chain (EPC) is used for the design of the process flow within one enterprise, supplement by other methods to cover all business views that are needed (organizational, data, activities, outputs). The ARIS House delivers all necessary methods for this step. For the collaborating partners only the data at the interfaces (marked with an I), that is the input respectively output data of the single process modules (resp. EPC), are relevant for the realization of the collaboration. Thus it is guaranteed that the enterprise-owned EPC is only internally visible.

Fuelled by the global need for organizational and output information, these parts of the local business process models can then be exported to a standardized Business Process Language like BPML. Process fragments are sent to all other network participants and can be integrated into their own process descriptions. After this configuration phase a global workflow is generated. It has to be visualised by an appropriate graphical method in order to gain knowledge of the common processes and to reduce the complexity of integrating the participating organizational units into one virtual unit. The Process Module Chain clearly and understandably represents the collaborative processes (cf. figure 4) [21]. It consists of single process modules or components, in which again more detailed EPCs, that contain the local processes, are lodged [22]. Process Module Chains are particularly suited for the illustration of collaborative

process flows because the single process modules form a logically terminated unit and the interfaces, located between the single modules, contain input data for the following modules, as shown in figure 4.

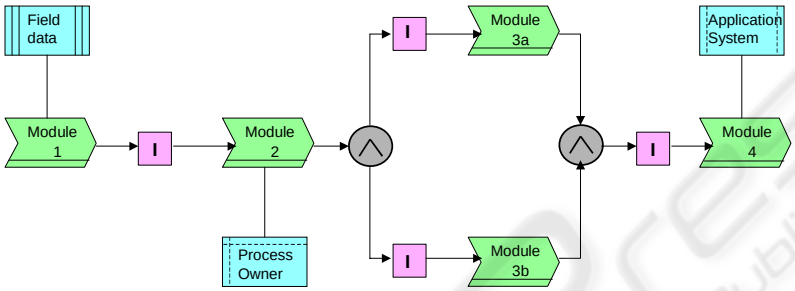

Fig. 4. Process Module Chain

At the time the interaction occurs between two partners, local knowledge is shared (bilaterally) between the partners, i.e. additional information, like data structures and semantics are exchanged. Updates of the local knowledge do not influence the network as network knowledge has to be available for all partners. This information is stored in the description of the interfaces in the Process Module Chain.

The collaboration partners have to continuously compare the result of the implementation with their goals and adjust deviations. Hitherto the management has obtained its knowledge about the company's success from figures of the past, e.g. cashflow, trading volume or profit made. The causes for fluctuations, requiring immediate counter measures, are not discernible. Until the problem is recognized, valuable time has elapsed. Therefore new measurement categories, which allow a reliable and contemporary evaluation of the process efficiency, are required. The information needed cannot be extracted from the record and transaction oriented applications alone. Key performance-indicators must be defined based on records, log-files, time stamps etc. These can be measured and analysed by means of intelligent tools [23].

The use of analytical tools in connection with their integration into functional systems, concludes the business process lifecycle from development, implementation up to controlling and the continuous improvement of collaborative business processes. The controlling function is a must when there is a high degree of uncertainty as with C-Business projects. The management can permanently control the implementation of the strategic collaboration configuration and promptly evaluate whether the expected added value potentials have been reached.

Integration of the partner enterprises is the basis for the configuration of the inter-organizational information systems. In order for the network to operate, an IT-infrastructure is needed that can seamlessly join the partly worldwide scattered parts of collaborative business networks into one unit.

3.3 C-Business Execution

To support the framework developed above an IT-architecture is needed that is process-driven and relies on fully developed standards and interfaces which are widely accepted [24]. Instead of closed systems that have been used so far, C-Business requires the integration of different applications. Component based architectures can be seen as a state-of-the-art approach to overcome these problems.

Process-driven emphasises the importance of the process models created on the preliminary layer. At the execution layer these models are used for process orchestration. Orchestration in this context describes the composition of web services in a process flow. In detail, it defines the complex interaction between web services, including the business logic and execution order of the interactions. These semantically defined interaction concepts describe how web services have to be organised so that one web service starts in time while the other stops so that the data transaction properly works out. Without orchestrating web services the overall context between the single process steps would be lost.

So far these semantics are stored in the isolated process descriptions and models (business process knowledge) on a conceptual level. However, the automation of cross-organizational business processes must be based on a system that allows the transformation of semantic into formal models. After the foundations, i.e. data and process integration, are laid, a system supporting not only this transformation but also activity coordination is presented in the next sections.

Data Integration
Collaboration partners must access data and applications in an easy and secure way. Standardized mark-up languages for exchanged documents like the Extensible Markup Language (XML) are designed for this purpose. But the meaning of mark-up tags, e.g. data fields in orders and bills, vary from one enterprise to another. There are a lot of promising efforts for standardization, but there is not one common standard. Therefore a conversion is still necessary to exchange documents automatically. Contrary to EDI, XML standards can be transferred into another more easily and they can simply be transmitted over the Internet.

Process Integration
With the use of XML the technological basis for interoperability has been established, the interoperability between the semantic business process definitions however is still missing. Efforts like BPMI's Business Process Modelling Language (BPML) promise standardization for the management of inter-organizational business processes that involve different applications, departments and business partners [25]. This standard, which is based on XML, complements existing B2B protocols like RosettaNet, BizTalk and ebXML. On the one hand BPML acts as an intermediary between business process modelling tools and IT. On the other hand BPML enables the interoperability between modelling tools. Besides, a wide acceptance of the Business Process Execution Language for Web Services (BPEL4WS) by BEA, IBM, and Microsoft as well as the newly finalized specification of the Web Services Choreography Interface (WSC-I) mainly driven by BEA, Intalio, SAP and Sun show the importance of such standardization efforts for interoperability [26]. While BPML is seen as more concep-

tually-oriented, the latter two focus on the transformation into the system-level by orchestrating web services.

Computer Supported Activity Coordination

For the computer supported activity coordination in enterprise networks an information system is required that supports this two step coordination. In a repository, which is logically centralized but can be physically distributed across the enterprise network, the global knowledge is stored. Especially conceptual models about the possible participants of coordinated or orchestrated output delivery, characteristics of their products and collaborative processes are stored there. The repository is similar to the idea of an UDDI repository for the retrieval of web services [27], but enriched with business logic and information about the conduct of business processes.

In order to automate inter-organizational processes the conceptual models are transformed into formal models that are used as configuration data for the orchestration of web services. The applications of the partners have to communicate bilaterally to negotiate the interface specifications based on the formal models, defined in the repository. The local knowledge is generated by this negotiation for a certain situation. After this collaboration task has ended no updates of configuration changes etc. are reported to any other party except at the time when a new direct interaction occurs. In this context multi-agent systems offer a solution to achieve an automated or at least semi-automated interface-configuration [28], [29], [30].

Front-End Integration

Beyond the described back-end integration a front-end integration is crucial for the acceptance and success of such a system [31]. Usability and worldwide access for the employee can be achieved through the use of web-based systems. Especially Enterprise Portals have proven their positive effects by unifying several web-based front-ends. The user has individual and context-sensitive access to relevant information combined with push mechanisms that actively provide just-in-time information. If the portal is run by several enterprises, or if both, customers as well as suppliers and partners of the enterprise, have access to the portal, it is called collaborative portal [32].

ERP II Integration

The described trend towards open integration architectures in business context can be found in the ERP II concept recently propagated by the Gartner Group [33], which stands for a flawless connection between traditional ERP-systems and add-ons like SCM/CRM-systems. Beyond this internal integration of systems external ERP-applications of suppliers or customers are connected. Such an integration faces the same integration problems, especially the question of knowledge-sharing with partners and of a common semantic paradigm to consolidate e.g. the meaning of business objects and related data. To overcome these problems the basic concept of local and global process-knowledge and the suggested coordination system described above can deliver important answers to the pitfalls of ERP II integration.

4 Vision and Realization in Research Projects

The vision of this paper is a framework that provides a generic solution concept, which is transferred subsequently into industry-specific reference models. By considering this framework collaboration efforts are conducted on a solid basis, i.e. business process management. Here the greatest demand for further research can be seen in the formulation of methods or the expansion of established process modelling methods for inter-enterprise use as well as in a methodologically sound transfer of process models into ICT solutions. Another aspect that requires further research is the use of supporting tools that ease the task of exchanging process models between different enterprises and to distinguish between private and public knowledge.

At the Institute for Information Systems (IWi) the CCBI bundles the activities in the research field Business Integration. The open research questions are subject of the project ArKoS (Architecture for Collaborative Scenarios), i.e. the development of an architecture for the management of collaborative scenarios consisting of methods, a tool support and an integration platform. Existing modelling methods are examined concerning their support for inter-organizational processes and redesigned in accordance to the new requirements. Models of choice will then be integrated on the meta level in an architecture and implemented prototypically in a modelling tool.

ArKoS uses the results of the successfully accomplished project InfoCitizen The project InfoCitizen, funded by the European Commission under the 5th Research Framework Programme, aims at creating a pan-European Information Architecture for European PAs as well as to develop specific information technology that supports this architecture and ensures a seamless information exchange between public administrations on a pan-European level. Moreover, with this solution the EPAs are enabled to provide transparent and integrated public services for their customers, i.e. citizens and businesses. Eleven organisations within five different EU-countries (Germany, Greece, Italy, Portugal, Spain) worked together for two years to succeed in the challenge of pan-European interoperability. A prototype of an agent-based interoperability platform with a service repository as described in the conceptual part of this article was developed. The business processes are stored in an XML-representation and the agent platform invokes dynamically the service offers which are implemented as distributed web services. With these components a real-life scenario was implemented.

ArKoS will now transform these foundations into a system that is able to handle project-based collaboration in the building industry. Thus the research fields Semantic Web, ontology, Process-to-Application, Real-Time-Enterprise(-Collaboration) and Business Integration will play essential roles in the project. The building industry serves as an application domain because services that require the coordination of numerous enterprises are generated in large projects exactly in this industry. At the same time the enterprise networks of such building projects are characterized by high dynamics and fluctuation. The practical reference models are implemented by software developing enterprises and validated in a test scenario by user partners from the building industry.

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