Applying Service Oriented Architecture in the Aerospace Industry

Jurga Kazlauskaite, Arsalan Minhas, F. H. Vogt
Telematics Department, Hamburg University of Technology
Schwarzenberg Strasse 95, 21073 Hamburg,Germany
Tel: +49-40-42878-3531
http://www.ti5.tu-harburg.de
{ jurga.kazlauskaite, arsalan.minhas, f.vogt }@tuhh.de

Abstract

This paper proposes the sequence of steps that are necessary to produce efficiently working Service Oriented Architecture for cross enterprise business processes and stresses the need for verification and programmatic support at every step of development. Verification of produced models at early stages allows the reduction of mistakes and assures that all important aspects have been included whereas programmatic support reduces the 'double' work and allows reducing project completion time.

Key words: *Service Oriented Architecture, cross enterprise business processes, verification, security, reusability*

About the Authors

Jurga Kazlauskaite is a research assistant at Telematics department of Hamburg University of Technology (TUHH). She obtained a B.Sc. (Honors) in Engineering Informatics from Vilnius Gediminas Technical University in Lithuania in 2001. She defended her Masters Degree in 'Information and Media Technologies' at the Hamburg University of Technology in September 2004 and in parallel to it gained 'Professional Masters degree in Global Technology Management' from Northern Institute of Technology. Her areas of interest are business process analysis and modelling, integration of IT and Management.

Arsalan Minhas is currently associated with Hamburg University of Technology for his Masters in 'Information & Communication Systems'. He did his graduation in Computer Systems Engineering from the NED University of Engineering & Technology, Pakistan in 2001. He worked as an Engineering Manager at Clickmarks Inc., USA and also served NED University as a visiting faculty member from 2002-03. He is the founder of International .NET Association (INETA) in Pakistan and served as the Country Leader for year 2003. Moreover he was the Secretary of IEEE Karachi Section for year 2003 and also chaired the IEEE Students Activities Committee (SAC) from 2001-03. His areas of interest include Ubiquitous/Pervasive Computing, Service Oriented Methodology, Distributed Systems and Middleware designing.

Friedrich H. Vogt is a professor in Computer Science and the head of Telematics department at the Hamburg University of Technology. He is teaching Transaction Processing, Operating Systems and Computer Networks. In 2004 he was the visiting professor at the Software Engineering Institute of the East China Normal University in Shanghai, China. He received his PhD in Computer Science from the Vienna University of Technology and got several appointments as a research fellow at SRI International in Menlo Park and as a visiting researcher at the International Computer Science Institute (ICSI) in Berkeley. In 2003 he worked with Leslie Lamport at Microsoft Research in Mountain View on Formal Methods for Web Service Protocols. His current research interests are focused on Service Oriented Architectures for distributed product lifecycle management applications in cross enterprise environments in the aerospace and shipping industries.

1. Introduction

As a result of mass customisation and due to the complexity of products in the aerospace industry, the size and complexity of the supplier networks are increasing rapidly. It is therefore crucial to assure the successful collaboration of the overall supply chain and to improve the cross enterprise communication processes. More efficient and faster communication would contribute to a better quality of the final products and reduced time-to-market due to shortened delivery times or faster reaction times to exceptions.

Service Oriented Architecture based on Web Services technology provides the flexibility, reuse and loose technology coupling needed to support vast supplier networks. The flexibility and reuse is needed because globally distributed supplier network partners can change over time, loose technology coupling is required since different companies use different applications running on different platforms for managing their work.

To assure the correctness of the developed solution and the best use of the technology the intermediate verification steps are needed. The information and knowledge obtained after document or process flow analysis and the investigation of user or company interaction patterns have to be approved by the process owners. Just after that it is recommended to proceed to the next step towards the final solution development.

The Telematics department of TUHH proposes the sequence consisting of six steps:

1. Depiction of document, data and information flows based on observations and collected data
2. Validation of workflows and cooperation patterns
3. Selection of Web Services protocols based on cooperation/business rule analysis, and examined cooperation patterns
4. Verification of selected protocols
5. Implementation of protocols
6. System validation.

An important aspect to stress is the need for programmatic support at each level of Service Oriented System Architecture creation, from requirements capturing and ‘as is’ status analysis (using tools like Adonis) to implementation of missing services and protocols.

The proposed sequence is set in to practise by a research initiative at the Telematics Department of Hamburg University of Technology that aims at strengthening the Small and Medium Enterprises

(SMEs) involved in the Aviation industry. The goal of the initiative is to offer a solution that would provide safe and correct collaboration base fostering innovation process of Airbus and supporting cooperating parties in fulfilling their contractual agreements.

Collaboration among companies will be improved and the product time-to-market decreased due to automation of certain process parts, more efficient exception handling and more transparent cooperation process. Cost reduction will also result from reduction of the amount of paper produced in the interaction between Original Equipment Manufacturer (OEM) and SMEs, better communication and ability to move at a fast pace from product design to production phase and delivery.

2. Specifics of Aviation Industry

Airbus is one of the world's two dominant civil aircraft producers with its more than 150 sites throughout the world and 16 development and manufacturing units spreading in France, Germany, Spain and the United Kingdom. Its share of the market grew steadily in 1980s [11]. In 2003 for the first time it gained the leaders position in the market. Today it is one of those industries where final products or services result from cooperation of a huge number of enterprises. The industry can be characterised by very complex and long life-cycle products (up to thirty-forty years), tight cooperation among companies of varying sizes leading to dependencies of different levels, non-planable R&D cooperations , changing consensus/conflict constellations [9, 10] and many iterations of the design and development processes. OEMs like Airbus are dependent upon performance and abilities of their strategic suppliers. A number of different cooperation directions like vertical cooperation between OEM and SMEs and horizontal between suppliers are to be considered while making proposals for improvement of the current supplier network. All partnerships reflect that aeronautics is a dynamic global business in which the drive for competitive advantage seeks out the best possible synergies, wherever they can be found. Collaboration is constrained by competitiveness rather than geography [11].

Around 80% of the production and design of different parts of an aircraft is outsourced or executed in collaboration with other enterprises [4]. Therefore SMEs are important players in this industry. The complexity of the supplier networks underlines the fact that only in the region of Hamburg there are approximately 500 supplier companies working directly or indirectly for Airbus [4]. The goal to stay competitive in the market pushes OEMs from aviation industry to redesign their logistics networks [5] and to integrate information systems from product engineering through production to delivery. The integration of several information systems shall not only speed up the communication and cooperation process but also makes it transparent. Therefore the improvements in '*document and data exchange*' sector would have a positive impact for the whole supplier network.

Development of new system also entails development of a subset of business rules that would be acceptable for both parties (OEMs and SMEs) and would stay compatible with the ones described in General Requirements for Equipment and System Suppliers (GRESS). GRESS comprises activities and documents; activities that need to be performed and documents that are required to be delivered by different suppliers while designing, manufacturing or delivering new or already existing products to OEM. Airbus seeks that in the future all of their suppliers will comply with the project structure proposed in GRESS, though not all the suppliers yet agreed upon. There are various reasons for the resistance. Some significant reasons are mentioned below:

1. Airbus states that after signing GRESS, the supplier agrees that invoicing and processing of shipment advises will be supported by an *EDI* (Electronic Data Interchange) and the corresponding interfaces will be agreed upon. However in practice it is being done through fax, e-mail or in paper form. When installing new system suppliers will be confronted with two major problems. Firstly, no standards for secure document exchange in cross enterprise environment exist today and secondly, installation of new EDI system would lead to additional high costs for the supplier.

2. Airbus requires delivery of *monthly* Lean Manufacturing, whole process metrics and status progress *reports*. Lean Manufacturing metrics are modelled to keep track of movement of resources and performance levels of different activities that companies use to eliminate all non-value added activities and minimize resources required for production. The problem here is that not all small and medium size suppliers use Lean Manufacturing metrics, so they would have to be developed, and monthly delivery might just cause too much of additional work. Since the situation of SMEs is not changing so dramatically over a month, no meaningful changes will be present in the metrics from one month to the other. Another problem which is not so easily seen is that not all SMEs have software systems that track the status of inventory, movement of workforces or production facilities which are needed to produce such a metrics.

3. Finally Airbus demands to choose a *single person* (Project Leader) from the company *for communication* with Airbus. This might not always be an optimal solution because project leader does not necessarily have all the knowledge needed when technical details among engineers have to be discussed. Thus the communication through the project leader could slow down the overall design process. Another argument to be mentioned here is that even if Airbus requires a single point of contact on the suppliers' side, it cannot assure that the same rule will be valid for Airbus too. In most of the cases up to now suppliers had to contact different people in Airbus within the scope of a single project.

However adhering to GRESS can result in many advantages like: integration of EDI systems between OEM and its suppliers will allow smaller companies to see the status of projects on the Airbus side, therefore they will be able to better plan their work and deliveries, the access to the information about maintenance operations could help suppliers as well to plan more precisely when and how many parts to produce for replacement.

Another important aspect is that time-frames for Airbus within which they promise to react to the requests received from their suppliers are not clearly defined or stated in any documentation which makes the overall process very unpredictable and error prone.

We will see how our proposed solution based upon Service Oriented Methodology can assist in addressing all these issues. It will not only solve the suppliers' concerns related to GRESS but will also make the vertical (between OEM and suppliers) and horizontal (among suppliers) workflows mature and more disciplined. All the parties will be able to communicate effectively because of transparent data and information exchange and will also be able to react faster to appearing exceptions and changing deadlines and priorities. This will result in overall reduction in production time and cost, speedy communication, enhanced co-operation and above all 'documents and data exchange' in a standardized way as outlined by SOA. Enhanced collaboration would also speed up the preparation of Design Definition Dossiers, which is often done in conjunction with SMEs.

3. How Service Orientation fits in?

Service Orientation (SO) is NOT a technology or a product but a paradigm or an approach to building Systems using Services which adhere to four tenets of Service Orientation:

1. Boundaries are *Explicit*
2. Services are *Autonomous*
3. Services share *Schema* and *Contract*, not *Class*
4. Service compatibility is determined based on *Policy*

A System is a set of deployed Services cooperating in a given task. System is built to change and adapt to new services after deployment. Service can be considered as an entity that is interacted with via message exchanges. Unlike Systems, they are built to last and their availability and stability are of critical importance. Services are fractals which means that a service can be composed of sub-services; sub-services can be composed of further sub-services and so on.

Although there are a number of parallels of SO with Object Orientation (OO) but there are some differences as well. There is a trade-off between ease of programming and flexibility. Services are mainly about reducing shared assumptions, more flexible while Object Orientation is mainly about ease of use, transparency, lots of assumptions and less flexible. In OO, complete fidelity with local contract exists, boundaries are harder to isolate, types are shared and not schemas, objects are tightly coupled and offers platform-based compatibility. Unlike Services reduce assumptions between services, boundaries are explicit, share schemas not types, are autonomous, and offers policy-based compatibility.

SO provides us an opportunity to rethink how we can design and architect tomorrow's systems by minimizing hard interdependencies, enhancing independence and easing delivery of composite business applications. It enables a high level of interoperability and makes explicit some of the core assumptions that compromise today's systems particularly around boundaries and locality.

The four principle tenets of SO offer various advantages. For architecture and development it provides: simplicity due to formal interaction model, correctness, implementation independence and dependency management. For IT and operations it offers: explicit interaction points that are more discoverable and operable, versioning, management, topology, independent deployment and crisp isolation of service capability from IT environment. Business benefits are: technology reuse resulting in cost savings, modelling business capabilities, serving the business (not vice versa), formalizing inter-departmental or inter-org relationships and expressing through service interaction and facilitation through outsourcing and focussing on core competencies.

The SOA is *usually* built from separate Web Services. Web Service is a software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a format that machines can process (specifically WSDL). Other systems can discover a Web Service (specifically via UDDI) and interact with it in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with XML serialization in conjunction with other Web-related standards (W3C). Service is the important concept. Web Services are the set of protocols by which Services can be published, discovered and used in a technology neutral, standard form. So Web services provide us with certain architectural characteristics and benefits specifically platform independence, loose coupling, self description, and discovery - and they can enable a formal separation between the provider and consumer because of the formality of the interface.

4. Our Approach

The creation of properly working flexible systems in today's business environment where different supply chain partners use a number of different applications installed on different platforms is just one of the challenges. Another critical factor is providing an insight about the companies order status to the customers and suppliers of an enterprise. It is almost impossible to push for totally new system solutions for huge enterprises because of the reliability, correctness, security and other factors tied with new implementations. It is therefore necessary to find ways to make existing processes more efficient, while making the best use of the systems implemented today. To realize this objective the current inflexible applications should be integrated with the help of additional services to provide needed flexibility, transparency and scalability.

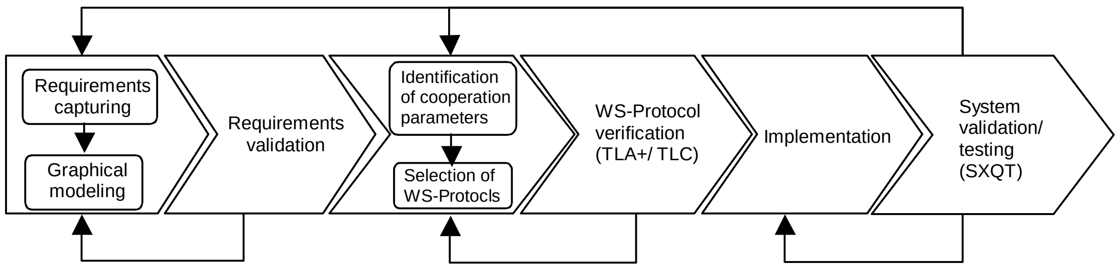

Figure1: System development steps

To enable the collaboration among various enterprise systems and with the goal to implement SO approach, development starts with the analysis of existing data and information flows. Captured requirements and observed interactions among different actors are depicted in a graphical view (figure 1, stage 1). For graphical representation we propose using actor perspective.

Having the diagram depicting actor perspective is a relevant issue since the second step of our approach is model validation. This can be done by demonstrating and discussing the produced models with the process owners. The perspective mentioned makes it easier for the owners of different process steps to identify themselves with the information presented in the diagrams and allows getting more precise feedback on the missing aspects. The use of graphical cooperation models including the actor perspective also allows verifying that all actual data and information flows are depicted.

The third step after modeling and verification is to derive the cooperation specific parameters like security, safety, messaging from the diagrams and feedback of the process step owners. Later on, based on the derived parameters, selection of the available WS-Protocols, which satisfy the requirements, follows. A large number of protocols that use the SOAP [16] conventions for message exchange are now under development [8].

To make sure the chosen protocols will work as intended, the verification of the successful coexistence of the selected protocols is advisable for determining errors at early stages. Checking for conformance at this stage is omitted by the industry today. Our model (figure 1, step 4) proposes validation using TLA+ - The Temporal logic of Action for concurrent reactive systems - a language for writing high-level specifications of concurrent systems [8]. Unlike most specification languages, it is based on mathematics rather than programming-language constructs. Mathematical models have to analyze the dependencies among different applications; for instance guaranteeing correct transaction rollback in case of a system crash. Otherwise it might lead to crucial mistakes in situations where actions taken by one application depend on data stored in other application.

After successful verification process final development steps and implementation can follow (figure 1, step 5).

Normally newly implemented systems have to under go extensive testing. Up to know testing was done manually and a number of standard and exceptional situations had to be simulated against which the application was tested later on. Simulation of test situations and testing itself requires additional time and man power. In our case implemented protocols are exposed to *permanent* automatic validation under real environment conditions with the help of Specifications using XQuery expressions on Traces (SXQT) [15]. SXQT specification technique allows detecting non-conformances in the occurring message sequences, when compared against protocol specification. The flow of real message exchange is used for the validation purposes to see whether the protocols work the way that was intended. The permanent validation is not limited to a number of simulated situations, the system is validated with each exception appearing, it does not require involvement of developers, excludes mistakes related to the human factor, informs developers whenever some deviations appear and in such a way supports developers in creation of conforming implementations. Validation using SXQT can be implemented for early prototypes, for final implementations or in real world working environments.

The proposed model with the verification following every stage contributes to creation of properly working flexible and extensible systems, while reusing current implementations. This approach enables exclusion of systems errors at the earliest stages possible and allows saving time and costs due to reduced number of man hours required for test situation simulation and maintenance of the system.

5. Case Study

For the purpose of internal and cross enterprise process analysis and to depict the interaction between an OEM and SMEs, the business processes between Airbus (OEM) and Innovint Aircraft Interior GmbH (SME) have been analyzed.

The data was collected by one of the authors that stayed at Innovint AG for one month on full time basis. The information concerning engineering business process (milestones, development process, Airbus requirements for equipment and system suppliers, product structure) was obtained, the study of existing documents related to various orders was made and employees involved in execution of different process steps were interviewed.

It was discovered that companies need to comply with certain steps and time spans for various milestones while designing and developing products for Airbus. They are precisely described in GRESS provided by the OEM. Telephones and faxes are still used very extensively for exchanging data and information in aerospace industry. EDI will be required for cooperation with OEM in the near future. On the other end, Innovint is using Harmony system [17] for Customer Relationship Management (CRM).

Complex interaction processes for different products were modelled after the requirements capturing phase. Production of the Innovint can be divided into two big groups: standard products and project products. The project products are single units developed and produced on special request. The workflow of the project products extends the standard product ordering process. Later validation of the developed models followed. The graphical business process representations were presented to and discussed with the owners of different process steps. After several revisions and model improvement cycles graphical representations were approved by the employees of the company.

Further on the approved diagrams were used to derive the relevant parameters of communication, data and information flows in a distributed business environment, as well as to identify the bottlenecks and get early alerts for application specific exception handling [8]. The outcomes of the research were documented in a form of Software Requirements Specification (SRS). SRS also describes requirements for the integration of the CRM software installed in the company with the state-of-the-art collaboration platform e.g. [12-14]. This solution will provide an insight to the project status at the Innovint for their customers and suppliers and will be used for recording of working patterns. The customers will be able to check their order status, see whether there are any delays and prove the availability of standard products of their interest. An insight to the project-order status will allow to better plan and coordinate cooperative design and development projects among the companies involved.

Prototyping implementing all identified distributed functions using the standard and proven WS-protocols has been chosen to avoid leaving out any significant information that was not well communicated in the requirements capturing phase. It will also help the users and designers of the future system to better understand and comment on the features and will allow us finalizing cooperation parameters. "Prevention of defects begins with better ways to capture, represent, and validate the objectives and requirements of systems we are trying to build..."[2]

Up to now the project members had to face the problem of making implicit knowledge of process owners explicit by depicting it in a graphical form. This moment is critical, since it allows later on more efficient integration of the relevant knowledge into the system developed. The difficulties arose because people in the company did not think about their work in terms of process and data flows and the engineering sub processes vary significantly depending on the type of the product.

With this project we try to introduce more transparency in cross enterprise business process, by reducing the number of media cuts and providing insight into Innovint order statuses for their customers and suppliers. We believe that our solution fulfils the need for future business benefits by helping employees and decision makers to be more productive, while allowing organizations to take advantage of their investment in existing systems. It will add value to the business by:

1. *Networking disconnected islands of data*. Many enterprises store information in multiple locations like file shares, individual users' hard drives, in multiple business applications and formats, or locked away in databases. Lack of structured content repository and no common infrastructure for distribution of the information are real bottlenecks for enterprises. Frequently, users must search multiple locations to find the right piece of information. This can be time-consuming and difficult, and sometimes users abandon the search before they find useful information.

   To understand their business and carry it out effectively, organizations must unify this information with a single point of access. We hope that our solution will ensure an easy distribution of information amongst customers, suppliers and partners having no common infrastructure among them. By tying together disconnected islands of data, organizations can capture and maintain the competitive advantage. The result is a more effective organization that can identify trends and react to them quickly.

2. *Integrating disparate business processes.* No portion of an organization's business is carried out in isolation. However, many business applications use proprietary protocols, do not integrate with other applications, and require their own user credentials to sign in. More and more organizations are looking for ways to integrate their business processes so they can streamline operations and share information more effectively.

   By providing Web Services interfaces, our solution is open for additional functionality and for integration into existing systems and processes. Using the standard Web Services protocols and adhering to the SO methodology provide an integrated environment for new and existing applications. The integration of Harmony CRM system in our case study proves that existing business processes can be integrated without abandoning investments in existing systems.

3. *Helping suppliers, customers, partners to collaborate effectively.* Teams need to communicate, share tasks, and work together in order to get their work done. Additionally, team members often need to work with people from other teams and divisions to complete tasks. This is even more difficult when people are located in different locations.

We believe that our proposed solution can help find, communicate, and collaborate with people no matter where they are located. It will allow users to receive notices and alerts about the changes made to the documents and the milestone plans, as well as about the deadlines of the tasks to be executed. For customers it will provide an access to documents, data, information, and applications. This can help organization to take advantage of many business-to-business opportunities. For example, customers can view the status of their orders; check the availability of a specific item, or possible delays. The implementation will also help to record the users working habits on which future improvements will be based. The goal of this system is to enable users to faster react to appearing exceptions because of an automated notification process and introduce more transparency to the data and information exchange process. The end result is an organization that is more efficient and effective in its work, which translates into better productivity and higher employee satisfaction.

6. Conclusions

The present paper describes the six steps approach for successful Service Oriented Architecture that concentrates on integration of currently running and future applications by providing Web Services interfaces. The investigations are being further backed up by the development of solution for Innovints' cooperation with its customers and suppliers, especially concentrating on the observed interaction with Airbus. Till this moment the first four steps: business process modelling, validation of requirements, selection of WS-Protocol and its verification/model checking have been completed. Prototype implementation is in progress which will be followed by the system validation. It is hoped that this work will demonstrate how companies affected by the tendency of mass customisation can still make best use of their IT technology investments by providing interfaces to their systems and implementing Service Oriented Architecture. If successful over a range of systems, the investigation will provide a base for a plausible theory of and efficient and effective SOA development.

Apart from any theoretical advance that this study will provide, it should, if successful, lead to the development of methods and tools for SOA creation. The study aims at contributing to creation of more advanced applications that greatly improve cross enterprise business process efficiency, transparency and flexibility by integrating a number of enterprise applications, unifying data and information stored and providing a single point of access for employees, customers and suppliers.

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