A Reference Architecture for Electronic Business-to-Business Collaboration Setup and Enactment Systems

A. Norta[1], P. Grefen[2], S. Angelov[2], and L. Kutvonen[1]

[1] Department of Computer Science*** , P.O. Box 68 (Gustaf Hällströmin katu 2b), FI-00014 University of Helsinki, Finland
(alexander.norta|lea.kutvonen)@cs.helsinki.fi

[2] Eindhoven University of Technology, Faculty of Technology and Management, Department of Information Systems, P.O. Box 513, NL-5600 MB, Eindhoven, The Netherlands.
(p.w.p.j.grefen|s.angelov)@tm.tue.nl

Abstract. The question what a business-to-business (B2B) collaboration setup and enactment application-system should look like remains open. An important element of such collaboration constitutes the inter-organizational disclosure of business-process details so that the opposing parties may protect their business secrets. For that purpose, *eSourcing* [37] has been developed as a general business-process collaboration concept in the framework of the EU research project CrossWork. The eSourcing characteristics are guiding for the design and evaluation of an *eS*ourcing *R*eference *A*rchitecture (eSRA) that serves as a starting point for software developers of B2B-collaboration systems. In this paper we present the results of a scenario-based evaluation method conducted with the earlier specified *eS*ourcing *A*rchitecture (eSA) that generates as results risks, sensitivity, and tradeoff points that must be paid attention to if eSA is implemented. Additionally, the evaluation method detects shortcomings of eSA in terms of integrated components that are required for electronic B2B-collaboration. The evaluation results are used for the specification of eSRA, which comprises all extensions for incorporating the results of the scenario-based evaluation, on three refinement levels.

1 Introduction

The collaboration between manufacturing companies in the B2B domain is complex from a business, conceptual, and technological point of view. Observing such collaboration, particular features are characteristic. An original equipment manufacturer (OEM) organizes the creation of value in an in-house process that is decomposable into different perspectives, e.g., control flow of tasks, information flow, personnel management, allocation of production resources, and so on. A complex product of an OEM typically comprises many components of which several need to be acquired from suppliers. The reasons for acquiring parts externally are manifold, e.g., the OEM cannot produce with the same quality, or an equally low price per piece, the production capacity is not available, required special know-how is lacking, and so on.

*** Technical Report ID: C-2010-2

Investigations about supply-chain collaboration in the EU research project CrossWork [30] have revealed a scenario as described in Figure 1. An original equipment manufacturer (OEM) rests on top of the depicted B2B-pyramid and is responsible for engineering a product and setting up the machinery and plant construction for production. On this first tier, producers assemble systems and modules stemming from suppliers of the second tier. On the third tier, suppliers are located that assemble components for the systems production of the second tier. Finally, suppliers of raw materials and standardized parts are located at the bottom of the supply-chain pyramid.

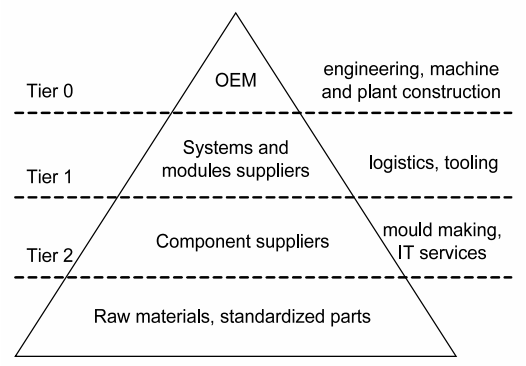


Fig. 1. Supply-chain hierarchy in a B2B-collaboration.

It is typical in such supply chains that the OEM wants to push the responsibility for accurate service provisioning down the pyramid to first tier suppliers while it tries to concentrate tight control on the first tier. The suppliers are requested to perform a mirroring of the particular parts of the in-house process that the OEM does not want to perform itself. In such a constellation, the OEM is considered a service consumer and suppliers are service providers. In an extreme case, the service consumer dictates the control-flow, data-flow, resources, and so on that must be specified in the services of a provider. Otherwise a potential service provider is not considered by a consumer if the first party can not assure the capability of process mirroring. However, in other industry domains, the opposite extreme is thinkable where a service consumer does not impose any restrictions on steps that create the desired service provisioning.

For a service consumer, finding a suitable partner is hampered by several factors. Firstly, experience shows that respective parties model their services using different methodologies. That way, it is difficult to communicate and decide to which extent process mirroring is possible. Practitioners lack a common concept with which interorganizational business process collaboration is expressible. Additionally, the parties are reluctant to disclose internal business details for fear of revealing their competitive advantages. That makes it even harder to assess the capability of process mirroring. Hence, given the described difficulties, service consumers and providers are con-

fronted with a considerable communication effort during the setup and enactment of B2B-collaboration.

To tackle the mentioned complex issues of B2B supply-chain collaboration, the eSourcing [11, 34–38, 40] concept was developed during the CrossWork project. eSourcing is a framework for harmonizing inter-organizationally business processes of service consuming and service providing organizations into a B2B supply-chain collaboration. Important elements of eSourcing are the support of different visibility levels of corporate process details for the collaborating counterpart and mechanisms for service-enactment monitoring and information exchange. Total visibility means that all process details are disclosed and partial visibility results in a disclosure of a process subset. With low visibility, no process details are disclosed with the exception of interfaces. For the process details disclosed, eSourcing comprises constructs for monitoring enactment processes. The support for information exchange enables business-data exchange between collaborating parties without endangering the correct termination of an eSourcing configuration.

Based on the elaborate investigation of eSourcing, a conceptual architecture for the setup and enactment of eSourcing configurations, eSA was specified in [35, 39]. This architecture comprises three refinement levels and is intended to serve developers as a means to either implement the entire application system or specific components as commercial off-the-shelve software. However, to be considered by developers as a reference architecture for the implementation of setup and enactment applications of eSourcing configurations, it is essential to evaluate the initial architecture from [35, 39]. The evaluation results expose deficiencies of the initial architecture and lead to the specification of the eSourcing Reference Architecture called eSRA.

The structure of this paper is as follows. First, Section 2 presents eSourcing-related work about inter-organizational business process collaboration . Furthermore, we present a discussion about scenario-based evaluation methods for reference architectures and justify our particular choice for one method that is applied in this paper for the evaluation of the initial eSourcing architecture. Section 3 describes relevant business aspects for the specification of eSA. The section commences with discussing how a separation of business-, conceptual-, and technological concerns is achieved, followed by an analysis of how collaborating business parties interact with each other during the setup of an electronic B2B-collaboration and an analysis of the construction elements required for the specification of an eSourcing configuration. Section 4 first presents a lifecycle of an eSourcing collaboration that is deduced from the business aspects that influence the specification of eSA. Based on the lifecycle, functional requirements are formulated and we check the functional completeness of eSA [35, 39]. In Section 5, the design approach and highest specification level of eSA are shown. Note that [35, 39] comprises further refining eSA specification levels. Additionally, Section 5 shows to which degree the eSA specification adheres to the functional requirements of Section 4. Next, Section 6 performs an evaluation of the initial eSourcing architecture in two ways. First, we show what architectural styles and patterns in eSA support specific non-functional requirements. Secondly, with a scenario-based evaluation method, we analyze shortcomings of the initial eSourcing architecture that need to be addressed with additional components. Section 7 presents eSRA including the specification updates for reme-

dying shortcomings found in the scenario-based evaluation of eSA. Finally, Section 8 concludes the paper and discusses future work.

2 Related Work

The following subsections first present work about related research projects and secondly about scenario-based evaluation methods.

2.1 Inter-Organizational Business Process Collaboration

Several research projects have investigated inter-organizational business process collaboration. In the WISE project [3, 25], a software platform is provided for process-based B2B electronic commerce that focuses on supporting a network of small and medium-sized enterprizes. While CrossFlow relies on cooperating pairs of autonomous workflow systems with a peer-to-peer relation, WISE employs a central workflow engine to control cross-organizational processes that are termed virtual business processes. In WISE, a virtual business process consists of a number of black-box services that are linked in a workflow process [3]. A service is offered by an organization that is involved in a WWW catalog of business processes, which are controlled by local workflow-management systems. Although the WISE project succeeds in orchestrating workflows of different collaborating organizations, it does not cater for a flexible degree of mutual visibility of business-process details as eSourcing does. Hence, eSA is specified in accordance with the requirement of catering for flexible visibility degrees. Differently to WISE, eSA includes components for collaborating parties to negotiate how much may be observed during the enactment phase.

In the CrossFlow project [42], the formation of virtual enterprizes is realized by dynamic outsourcing. A service matchmaker matches service offerings and service requests. Based on the resulting electronic contract, a service enactment infrastructure [16] is established dynamically that employs workflow technology. CrossFlow has an external level that spans across organizational domains in which the process is part of a contract specification. The workflow-specification language of the workflow-management system IBM MQSeries Workflow [1], forms the internal process level. Differently to eSourcing, the shortcoming of CrossFlow is that the service provider is not able to insert tasks that are not a lower process-level refinement, but that extend the business process on the highest level. At the same time it should be ensured with verification-tool support that a refinement by inserted tasks does not violate the service provision behavior a consumer demands. eSA comprises components for the verification and evaluation of B2B-collaborations. With verification we mean checking certain aspects of a collaboration such as control-flow, while evaluation refers to testing the enactment of entire business processes.

In the CrossWork [35] project, the objective has been pursued to develop automated mechanisms for allowing a dynamic workflow formation and enactment, enabling a collaboration and production synergies between different organizations. CrossWork uses *eSourcing* [11, 34–38, 40] as an integral concept that focuses on matching on an external level conceptually formulated service-consuming and service-providing processes.

2.2 Scenario-Based Software Architecture Evaluation Methods

For the specification and subsequent evaluation of eSA, we use a scenario-based method. Below, an overview of the available methods is presented together with their differentiating characteristics.

The *S*oftware *A*rchitecture *A*nalysis *M*ethod (SAAM) [8, 19] is the initial scenario-based evaluation method developed for assessing the quality attributes of a reference architecture. SAAM supports architects to reason about software-system quality without offering assessment metrics or tool support. The evaluation steps of SAAM start with the development of scenarios, followed by a description of the architecture. Next, a classification into direct and indirect scenarios takes place together with a prioritization. While all events of a direct scenario are fully supported by the architecture, changes are required to achieve a total support of all events that comprise an indirect scenario. The latter scenario type is individually investigated to determine the extent of architecture change. Two or more scenarios interact when their evaluations indicate changes for the same component of an architecture. To avoid such a situation, the respective component must be modified or divided into sub-components. The final step of the SAAM method is a weighing of the scenarios relative to their importance for the architecture's success. The weighing is instrumental for determining the overall ranking of multiple architectures.

The *A*rchitecture *T*rade-Off *A*nalysis *M*ethod (ATAM) [8, 20] is based on SAAM and also explores quality attributes. However, differently to SAAM, a greater emphasis is put on the interdependencies between these quality attributes. For this method it is recommended to evaluate in several workshop sessions. The initial workshop involves a presentation of the reference architecture together with its business aspects to a group of three to six expert evaluators who then elicit, concertize and prioritize the driving quality attribute requirements. To support this phase, a quality-attribute-utility tree [20] is created that is specified down to the level of scenarios, annotated with stimuli for architecture components and their responses, and prioritized. In a followup workshop, nine to fifteen related evaluators and project-related personnel evaluate the results from the first workshop. The chosen scenarios are analyzed and specified in detail. During this step, the architectural risks, sensitivity points, and tradeoff points are identified. *Risks* are architectural decisions that have not yet been made. *Sensitivity points* are properties of one or more components in the reference architecture that are critical for achieving a particular quality attribute response. *Tradeoff points* are properties that affect more than one attribute and that are sensitivity points for more than one attribute. Finally, the ATAM results are summarized in a report. Note that it is important in ATAM to cover the quality attributes where possible with so-called attribute-based architecture styles [22] (ABAS).

The *A*rchitecture-*L*evel *M*odifiability *A*nalysis (ALMA) [6, 24] is developed for assessing the software-architecture modifiability by employing a set of quality indicators. ALMA consists of four steps and commences with setting the analysis goal, followed by a presentation of the architecture. Next, change scenarios are elicited that play a role in an architecture's modifiability. After evaluating the change scenarios against the earlier set goals, an interpretation of the results is presented.

For completeness, two additional evaluation methods must be mentioned. The *C*ost-*B*enefit *A*nalysis *M*ethod (CBAM) [8, 18] includes as a criteria the costs that need to be considered among the tradeoffs based on the ratio "benefit divided by cost". Finally, the *F*amily-*A*rchitecture *A*ssessment *M*ethod called (FAAM) [9] is a method for the architecture assessment of information-system families. FAAM focuses on two related quality aspects, namely interoperability and extensibility.

For the development and evaluation of eSA, we choose an adjusted version of the ATAM method as it is more systematic than SAAM and puts more emphasis on the establishment of a detailed requirement-attribute hierarchy. The ALMA method is not suitable for this paper because of its strong focus on exploring primarily the modifiability of architectures. The CBAM method is not a suitable method because a cost analysis of eSA is not the focus of the architecture. Finally, FAAM is not applicable in the initial specification of eSA presented in this paper. Instead, FAAM may be considered as a suitable method in followup evaluations of the interoperability and extensibility requirement attributes.

The following section discusses which business-driving factors eSRA has to cover in its architecture specification. Furthermore, the business aspects are used for formulating functional requirements for the eSA specification.

3 Business Aspects for eSA

For finding the relevant business aspects for eSA, we conducted case studies in the CrossWork [30] project with industry partners in which the supply-chain setup phase was investigated. The case studies directed us on a more detailed level to collaboration frameworks and concepts that must be considered for automating supply chains. In

As a result, this section first explains in Section 3.1 the collaboration framework of dynamic inter-organizational business process management (DIBPM) followed by a presentation of a three-level collaboration framework in Section 3.2 that achieves a separation of concern. Section 3.3 discusses the eSourcing concept that is embedded in the DIBPM and three-level collaboration framework. Finally, in Section 3.4 the business aspects for eSourcing for the interactions between collaborating parties during the setup phase and for eSourcing construction elements.

3.1 Dynamic Inter-Organizational Business Process Management

The framework of DIBPM [13] offers a model for addressing the need of organizations for dynamically bringing together a service consumer and a service provider over internet-based infrastructures where the service is a business process. To do so, DIBPM merges service-oriented business integration (SOBI) and workflow management concepts. The setup of DIBPM-based business collaboration is a client-server relationship where one party offers a service that is integrated into the process of a consumer.

In DIBPM, a dynamic inter-organizational business process is formed dynamically by the (automatic) integration of the subprocesses of the involved organizations. In this context, dynamically means that during process enactment, collaborator organizations

are found by searching business-process market places and the subprocesses are integrated with the running process. Related issues to DIBPM are the definition and identification of processes, the way compatible business partners find each other efficiently, the dynamic establishment of inter-organizational processes, and the setup and coupling for process enactment.

3.2 Separating Concerns in eSA

In order to manage the complex business, conceptual, and technological collaboration issues of DIBPM, a three-level framework [14] is a suitable model. The bottom of Figure 2 shows the internal level that caters towards a heterogeneous system environment. Often organizations support their business processes by containing them in a hard-coded way in legacy systems. Examples of such legacy systems are applications for enterprise-resource planning, databases, accounting systems, applications for human-resource management, and so on. If the business processes of an organization are known and modeled, they are directly enactable by process-management applications, e.g., by intra-organizational workflow management systems. Companies are reluctant to directly link their internal-level legacy systems inter-organizationally to safeguard their information infrastructure and because of the fear they could disclose business internals that result in a loss of competitive advantages.

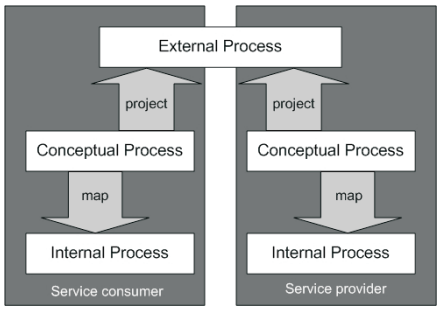


Fig. 2. A three-level business process framework.

At the conceptual level, the business processes are designed independent from infrastructure and collaboration specifics. Conceptual processes are mapped to their respective internal level for enactment. If the conceptual-level processes are supported by a service-oriented architecture, their enactment allows the orchestration of web-service wrapped legacy systems that are located on the internal level. For the conceptual level it is important that collaborating parties can use a common denominator for inter-organizational collaboration harmonization.

The external level stretches across the domains of the process initiator and responder. Parts of the conceptual processes are projected to the external level and compared by the collaborating parties. That way, the parties investigate the demands of service

consumption and the ability of service provisioning. Since it can suffice to project a subset of process details to the external level, an organization can determine which business internals should remain hidden from the counterpart. The process-based collaboration is automated and dynamically forged.

3.3 The eSourcing Concept

The eSourcing-based [11, 34–38, 40] supply-chain collaboration represents a structure-based approach of business-process matching that focuses on the structure (or behavior) of the process itself. eSourcing resembles the hierarchy depicted in Figure 1 where OEMs demand from the suppliers a mirroring of out-sourced processes in order to engage in the formation of a supply chain to avoid enactment problems [35–37].

eSourcing is instrumental for establishing inter-organizationally harmonized business-process collaboration. Harmonization refers to the external-level structural matching of business processes, i.e., the control-flow properties of the externalized processes are compared. In the context of DIBPM, eSourcing is defined as a framework for harmonizing on an external level the intra-organizational business processes of service consuming and service providing organizations into a B2B supply-chain collaboration. Important elements of eSourcing are the support of different visibility levels of corporate process details for the collaborating counterpart and mechanisms for service monitoring and information exchange. In [11, 34–38, 40], concrete eSourcing examples are contained. For this paper we focus on high-level aspects of the eSourcing concept that are relevant for the specification of eSA.

3.4 Extracting Business Aspects

The following method is pursued to explore eSourcing business aspects for the interactions between collaborating parties during the setup phase. Additionally, the eSourcing construction elements are explored. The interaction aspect focuses on the way how a service consuming and a service providing party interact with each other during the setup phase of a B2B supply chain with the objective of aligning their respective intra-organizational business processes on an inter-organizational level. On the other hand, the construction elements are essential for specifying an eSourcing collaboration.

On a refined lower level, eSourcing contains several business-aspect dimensions in the form of axes that create a multi-dimensional space. On each axis, respective dimension values are located that detail the refining eSourcing aspect an axis represents. By taking a subset of axes, a logical space is created that represents a particular aspect perspective. The respective logical spaces for the interactions of collaborating parties during their setup phase and for eSourcing-construction elements are derived from the higher-level business aspects of DIBPM and the three-level framework. The dimensions of the logical spaces are instrumental for deducing functional requirements that are guiding for the specification of eSA.

Below, two different multidimensional spaces are presented that emphasize separate aspects of eSourcing configurations. First, a two-dimensional space depicted in Figure 3 guides the exploration of the interactions of collaborating parties during the setup phase in eSourcing. Secondly, the three-dimensional space depicted in Figure 4 focuses on

features from which construction elements are deducible. These construction elements are building blocks of eSourcing specifications.

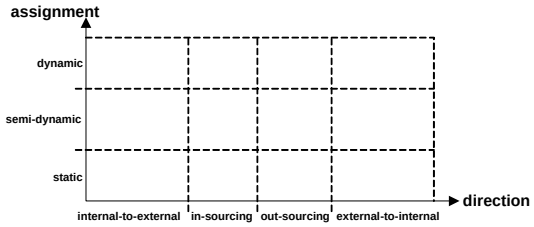


Fig. 3. Dimensions and values of interaction patterns.

eSourcing-Interaction Aspects: Figure 3 shows axes that create a two-dimensional space. On every axis the dimension further refining values are located. One dimension is called *assignment*, which focuses on the way a service provider is chosen for an eSourcing configuration. The values on the *assignment* dimension state to which degree the collaborating parties know at the beginning of an interaction that they collaborate with each other during the enactment time of an inter-organizational business process configuration. *Static* assignment means the collaborating parties already know before setup time they surely collaborate with each other. In the *semi-dynamic* case, the number of collaborating parties that engage in a setup phase is limited at the beginning and therefore known from a pre-specified pool. However, only at the end of the setup phase it is clear who collaborates. On the other hand, *dynamic* assignment means the collaborating parties bid in an anonymous market for service provisioning and/or consumption and only towards the end it is clear who collaborates during enactment.

The other dimension depicted in Figure 3 is named *direction* and focuses on the external-level harmonization of inter-organizational business process collaboration. Thus, this dimension describes the dependencies between the processes on the conceptual- and the external level of an eSourcing configuration.

The *internal-to-external* assignment direction means the collaborating parties have internal processes that are only harmonized externally at the end of their setup interaction. Both the service consumer and provider have established business processes in their domains. The consuming organization considers a part of its in-house process to not be core business. On an external level, the consumer and provider engage in negotiating a consensus process that accommodates their already existent respective internal processes.

Likewise, the assignment direction *in-sourcing* means a service provider has a service that is subsequently integrated into the process of a service consumer. Thus, external harmonization is only performed at a later stage. The service provider sets up a process in its own domain and subsequently exposes a subset of the process details

publicly. Compared to the exposed version, the internal process contains additional refinement steps that remain opaque. Next, an interested service consumer adopts the exposed process and integrates it in the in-house process.

Out-sourcing is similar to in-sourcing with respect to harmonization. However, now the consumer starts the interaction with externalizing a service demand first. A part of an organization's in-house process that should be carried out by a third party, is demarcated into a subprocess. Next, the subprocess is taken over by an organization that agrees with offering the service. In the domain of the service provider, further refinement of the service may take place that remains opaque to the service consumer. The subprocess in the domain of the service consumer and the refined process in the domain of the provider are linked with each other and the service consumer starts with enacting of the created inter-organizational configuration.

Finally, the *external-to-internal* dimension means that external harmonization is the starting point of interaction and the collaborating parties set up internal processes at a later stage just before enactment starts. The service consuming and providing organizations start with negotiating process properties on an external level. When they have reached consensus, both parties take over the publicly agreed-upon process for their internal domains. In the domain of the service consumer the adopted process becomes a subnet of a bigger inhouse process, while in the service provider's domain further refining process steps are inserted.

For the setup phase of an eSourcing collaboration only one assignment and one direction value are combinable to describe the nature of interaction between collaborating parties. Thus, following Figure 3, there are 12 possible combinations. In [34–36, 40] further details about the setup phase of eSourcing collaborations are available.

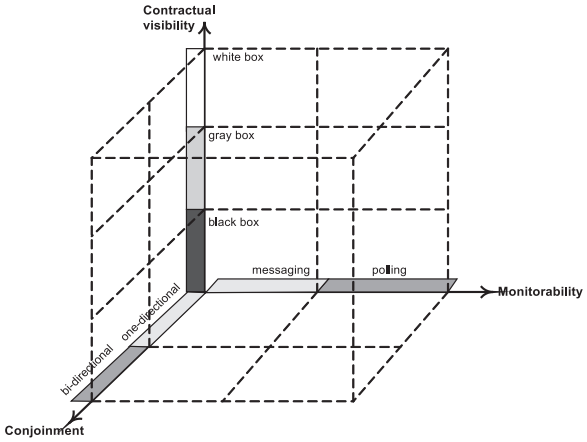


Fig. 4. Dimensions and values of the eSourcing perspective.

eSourcing-Construction Aspects: The cube depicted in Figure 4 is created by three axes representing different eSourcing dimensions on which values are positioned. The created multi-dimensional space is instrumental for deducing eSourcing-construction elements for protecting internal business details, ensuring data exchange that adheres to correct control-flow, and for permitting the service consumer a controlled observation of the service provider's enactment progress. Correspondingly, the axes of the multi-dimensional space of Figure 4 represent the aspect dimensions called contractual visibility, conjoinment, and monitorability [34–36, 40]. Based on experiences from modeling eSourcing configurations during CrossWork case studies, further refining attributes exist that are depicted in Figure 4 on the axes.

The cube dimensions and values of Figure 4 are described as follows. Contractual visibility focuses on how much process detail is disclosed to a collaborating counterpart. The values are regarding the amount of business-process nodes from the domain of a collaborating party that are projected to an external level and visible to the counterpart. First, a *white-box* value means nodes of a process part to be sourced are externalized. In case of a *black-box* value, only the interfaces of that process part are projected. Finally, the *gray-box* value means the interfaces and a subset of the nodes and arcs of the externally sourced process part are projected.

Conjoinment focuses on the exchange of business information between the domains of the collaborating parties. Consequently, the business processes within the domains contain equal conjoinment constructs. *One-directional* conjoining implies that there is one *out* or *in*-labelled node present handling the exchange between the domains of a service consumer and provider. *Bi-directional* conjoining is initiated by an *out*-labelled node to the domain of the collaborating counterpart that returns the communication exchange immediately to the initiating party.

Monitorability covers the way how nodes in the consumer's and provider's domain processes are linked with each other via constructs of the values termed *messaging* and *polling*. The nodes of the sourced process part that are externalized are connected to nodes in the corresponding service-provider process. The degree of monitorability of service provisioning for a service consumer is increased by the amount of nodes that are linked with monitorability constructs. At a minimum, all interface nodes of both domain processes need to be linked with each other. Additional nodes may be linked that belong to the respective business processes of service consumers and service providers. In [35, 40], details about eSourcing construction and interaction features are described.

4 Deduced Requirements for eSA

After discussing business aspects and requirement attributes stemming from the eSourcing concept and its broader framework of DIBPM, we specify a lifecycle for eSourcing configurations in Section 4.1. Based on the lifecycle it is possible to deduce functional requirements for eSA. Finally, non-functional requirements for eSA are presented in Section 6.1. Functional requirements cover specific behaviors of a system while non-functional requirements specify criteria that can be used to judge the operation of a system, rather than specific behaviors. Other terms for non-functional requirements are quality attributes and quality of service requirements.

4.1 Functional Requirements

Before deducting functional requirements, we first infer from the business aspects of Section 3, the lifecycle of Figure 5 for setting up eSourcing configurations.

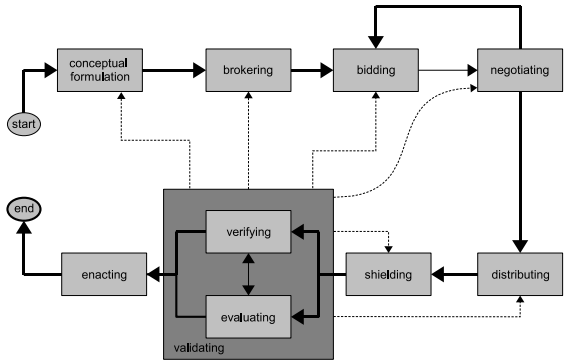


Fig. 5. A lifecycle for setting up an eSourcing configuration.

Based on the lifecycle of Figure 5, we deduce for eSRA the functional requirements listed below.

a.) Support for the conceptual formulation of business processes and their accompanying rules.
For the respective conceptual-level processes of collaborating parties, modeling components must be available. In order to prevent a constant reinvention of business-process constructs, it should be possible to store in and retrieve from a database such conceptually formulated constructs.
b.) Brokering capability of projected business processes.
Both the service consumer and the service provider must be able to place their projected business processes into a broker environment of a trusted-third-party service. This functionality is important for collaborations in an anonymous collaboration environment, where the potential business parties do not know each other or where it is of interest to engage in a bidding procedure for either service provisioning or service consumption.
c.) Bidding capability of projected business processes.
The bidding environment must be offered as a trusted-third-party service. Service offers and service requests must be searchable for potential business partners who must be enabled to place bids. The collaborating counterpart should be able to evaluate the bids and choose the best deal while rejecting all others. Once the bidding is over, the registered service consumption or service provisioning is removed.
d.) Negotiation support for setting up an electronic B2B-collaboration with known collaborating parties.

When collaborating parties have found each other, they need a platform for starting the contracting negotiations on the external level of an electronic B2B-collaboration. This negotiation involves the projection of business processes to the external level until a matching is achieved that establishes a consensus between the service provisioning and service consumption. A trusted-third-party service must verify if such a matching of business processes is achieved. Additionally, the collaborating parties must negotiate to which extent it is possible for a service consumer to monitor during enactment time the progress of service provisioning.

e.) Distribution and shielding of business processes and legacy systems on concern-separating three levels.

This requirement must be realized by grouping components on several levels to serve distinct purposes. The external-level components support the establishment of inter-organizationally harmonized business processes. The conceptual level components achieve an abstraction from technological details of the lower level legacy systems. Additionally, the conceptual level translates the data exchanges between the external and the internal level. Local enactment components need to remain shielded on the internal level for reasons of business privacy and security. The legacy systems should only be linked via the conceptual level with the inter-organizationally harmonized business processes.

f.) Validation of electronic B2B-collaborations.

From a control-flow point of view it is important to verify an electronic B2B-collaboration for correct termination [35–37]. A verification must ensure that a service provisioning internally adheres to what is externally promised to a service consumer. Verification must also cover other perspectives than control-flow, e.g., data-flow, resources, transactional properties, and so forth. Although a verification of different collaboration perspectives must be performed, errors may still occur when all perspectives are enacted together. Hence, an evaluation component for business processes must be available for a-priori test enactment.

g.) Enactment of a ready electronic B2B-collaboration.

When the setup phase is completed, the enactment of an electronic B2B-collaboration commences. The actual enactment components must be present on an internal level for coordination legacy systems. On the other hand, additional enactment components on the external level need to coordinate the internal components of the respective collaborating parties.

The established electronic B2B-collaboration must be checked in a *validation* activity hat may result in moving back to earlier lifecycle steps to correct specification errors. In Figure 5, the validation activity is depicted as consisting of lower-level activities, namely *verifying* and *evaluating*. In the first case, services are verified for mistakes in different perspectives, e.g., for deadlocks in the control-flow perspective, binding mistakes of data-flow in messages, and so on. In an evaluation of an eSourcing configuration, the correctness of all perspectives is checked in test runs. If a validation error occurs, i.e., either the validation or evaluation of an eSourcing configuration fails, earlier steps of the lifecycle must be re-performed. In Figure 5 such moves back in the lifecycle are depicted by dashed arcs.

Next, we present the approach taken for the specification of eSA. Below, only the highest level of the eSA architecture is shown for which [35, 40] contains two additional

refinement levels. For brevity, we do not show those eSA refinements here. However, an updated version of the refinement levels are shown in the sequel of this paper for eSRA specification.

5 Specification of eSA

Software development consists of three main phases, i.e., the analysis, design, and implementation phases [27]. A reference architecture for the domain of electronic interaction between collaborating business parties embodies essential design principles and specifies the functionalities that must be delivered by such an electronic B2B-collaboration system. Thus, a reference architecture serves as a starting point for software developers who are occupied with designing and implementing an information system for supporting the automated setup of business collaboration.

Conceptual architectures (also known as logical architectures) facilitate the understanding of the interactions between components and the functionalities provided by the system, and are consequently a good technique for the definition of reference architectures. The proposed reference architecture of this paper serves as a foundation in the design and development of B2B-collaboration systems.

Section 5.1 first explains the eSRA design approach, followed by Section 5.3 that shows what components satisfy particular functional requirement on which eSA collaboration level. Note, in [35, 40] the second and third eSA refinement levels are contained.

5.1 Design Approach

The functional requirements stated in Section 4.1 are used for deducing components and assigning them in the eSA specification that separate concerns as in the three-level business process framework of Figure 2. eSA is designed in accordance with the principle of functional decomposition of a system. This decomposition is also known as *separation operation* and based on the part-whole principle [6]. Thus, at each level of eSA, the identified components provide functionalities that do not overlap with the remaining components that are located at the same level. To achieve completeness, eSA is designed in a top-down way. As a result, eSA's functionalities and interactions are addressed in a step-by-step manner from a high level of abstraction on the top and on lower levels the detail gradually increases.

5.2 First Detail-Level of the eSourcing Reference Architecture

The highest abstraction level of eSA is shown in Figure 6 with two collaborating parties that contain the same set of components distributed across an external, conceptual, and internal level [14]. The gray shaded boxes represent components and arcs depict data exchanges between them.

The *eSourcing middleware* is replicated on the respective external levels of collaborating parties. This component is the main enabler of interoperability and direct information exchange exists between the eSourcing middleware of each collaborating party to synchronize the respective components. Between the collaborating counterparts, a

component is located termed *trusted third party* that exchanges business-relevant information with the eSourcing middleware. A trusted third party is necessary for several reasons that result from satisfying the functional requirements *b*, *c*, and *d* (see Section 4.1). Firstly, collaborating parties expose service requests or service offerings to the trusted third party for public evaluation. Secondly, the trusted third party performs a verification of services and checks quality features of eSourcing configurations before enactment. If collaborating parties perform verifications and checks of eSourcing configurations themselves, they would need to reveal competitive secrets to each other, which is undesirable.

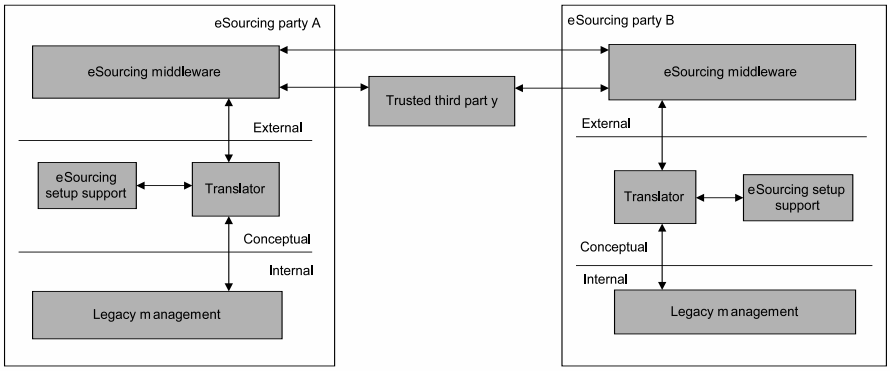


Fig. 6. Highest level of eSRA specification.

The conceptual level of Figure 6 depicts two components, namely the translator and the eSourcing setup support. The *translator* component exchanges information and translates it between the components located on the external and internal level. The *eSourcing setup support* contains tools for modeling business rules and processes. Finally, the internal level depicts a *legacy management* component that interfaces with the translator component of the conceptual level.

Next, we investigate which eSA components satisfy respective functional requirements. We reiterate that the objective of this paper is to present the specification eSRA. However, on the route to this objective, scrutinizing eSA is essential so that eSRA contains updates that address detected eSA-deficiencies.

5.3 Functional Completeness of eSA

The components of eSA are listed in Table 1 where they are separated in accordance with the supported functional requirement from Section 4.1 and the architectural refinement level in which the components reside. The alphabet in the left column of Table 1 corresponds to the alphabet of the functional requirements in Section 4.1 and it also corresponds to the paragraph alphabet below.

Functional requirement	Refinement level	eSA Component
a	1	eSourcing setup support
	2	Pattern knowledge base, Rules modeler, Process modeler, Workflow composer,
b	1	Trusted third party
	2	Service broker
	3	Template search engine, Notifier
c	1	Trusted third party
	2	Auction service
	3	Bid manager
d	1	eSourcing middleware, Trusted third party
	2	Contracting client, CE-translator, Coordination Interface
	3	CE-projector
e	1	eSourcing middleware, Legacy management
	2	Global Rules Engine, Global WFMS, Coordination Interface, Local WFMS, Local rules engine
f	1	eSourcing setup support, Trusted third party
	2	Verifiers (external and internal) CE-translator, CI-translator, Data exchangers
g	1	eSourcing setup support, Legacy management, eSourcing middleware, Translator
	2	Global Rules Engine, Global WFMS, Coordination Interface, CE-translator, CI-translator, Data exchangers, Local WFMS, Local rules engine
	3	Enactment monitors, Conjoinment monitors, Enactment engines, CE-projector, CI-projector

Table 1. Coverage of functional requirements by eSA components.

a. With respect to supporting the conceptual formulation of business processes and their accompanying rules, the highest refinement of eSA comprises the *eSourcing setup support* component on the conceptual level. On the second refinement level of the eSourcing setup support, the *pattern knowledge base* supplies conceptually formulated constructs that constitute building blocks for the conceptual formulation of business processes, which are created with the *rules modeler*, *process modeler*, *workflow composer*, and the supporting databases.
b. The brokering capability of projected business processes is realized in eSA with components contained in the *trusted third party*. On the second refinement level, the *service broker* component and its connected process-snippet database allow collaborating parties to submit service requests and service offers. Contained in the service broker, the *template search engine* allows to search the service library database. Furthermore, the *notifier* component actively informs a party if she has been specified in a service request or offer as a preferred collaboration candidate.
c. The bidding capability for projected business processes is realized in the *trusted third party* with the *auction service* component. On the third eSA refinement level, the *bid manager* allows the placement and retrieval of bids that are stored in the bidding library database.
d. The setup support of an electronic B2B-collaboration involves the *eSourcing middleware* and the *trusted third party*. On the second refinement level, the *contracting client* component together with the *coordination interface* forms a platform where the setup can be negotiated. In [4], details about a contracting client refinement are contained. From the *CE-translator* component, the contained *CE-projector* ensures that conceptual level processes are projected to the contracting client.
e. For avoiding the direct linking of business processes and legacy systems, eSA provides components that are located on the external, conceptual, and internal level (see Figure 2). Hence, on the first refinement level of eSA, the *eSourcing middleware* and *legacy management* components cover this functionality requirement. On

the second refinement level, the components *global rules engine*, *global WFMS* (workflow management system), and the *coordination interface* of the eSourcing middleware are needed. From the legacy management, the contained *local WFMS* and *local rules engine* are required. With the coordination interface, the global rules engine and global WFMS of collaborating parties are coordinated.

f. The verification and evaluation of electronic B2B-collaborations is supported by components contained in the *eSourcing setup support* and the *trusted third party*. In the first case, internal *verifier* and *evaluator* components allow a local verification and evaluation of conceptual business processes. When these business processes are linked inter-organizationally, the *verifier* component of the trusted third party allows a verification of the overall process without forcing the collaborating parties into revealing business secrets to each other.

g. For the enactment of a ready collaboration configuration, eSA provides components from the *eSourcing setup support*, *legacy management*, *eSourcing middleware*, and *translator*. Hence, from the eSourcing setup support, the components termed *global rules engine*, *global WFMS*, and the *coordination interface* are required for enactment support. Furthermore, the *CE-translator*, *CI-translator*, and both *data exchangers* of the translator ensure a functioning link between the external and internal level during enactment. From the legacy management, the *local WFMS* and the *local rules engine* components orchestrate the service-wrapped legacy systems.

In summary, the evaluation shows that eSA covers all functional requirements that Section 4.1 states. Table 1 depicts which components of eSA cover functional requirements. Next, we discuss non-functional requirements that eSA must adhere to.

6 Evaluation of Non-Functional eSA-Requirements

The structure of this section is as follows. Firstly, non-functional requirements for eSA are presented in Section 6.1. In Section 6.2 we discuss an ATAM-based evaluation of eSA that investigates how architectural styles and patterns [6] in eSA ensure that the adherence to non-functional requirements. Architectural styles comprise a description of component types and their topology, a description of the pattern of data and control interaction among the components, and an informal description of the benefits and drawbacks of using a particular style. Next, Section 6.3 discusses the results of eSA-evaluation workshops with experts and industry that show shortcomings of the initial eSourcing architecture that are used for an updated of the initial specification.

The eSA evaluation took place in workshops with experts from the domains of software engineering and service-oriented computing for finding risk, sensitivity and trade-off points, and non risks. Additionally, in the workshops the most relevant detected scenarios for the use of eSA-compliant systems were further investigated with the objective of finding deficiencies result in the specification of eSRA in the sequel of this paper. All evaluation results were generated in four expert-workshop sessions to produce all results while the ATAM documentation proposes to use only two workshops. Note that in [35, 39] the initial eSA-specification can be found.

6.1 Non-Functional Requirements

For eSA, the division of non-functional requirements from [5] is used that distinguishes between requirements that are observable via execution and those that are not. In the first case the requirements are performance, security, availability, functionality, and usability. In the latter case, the requirements are modifiability, portability, reusability, integrability, testability. Finally, we consider requirements on the architecture, namely completeness, feasibility, scalability, and applicability. First, we specify eSA system requirements that are *not discernable at runtime* because their investigation requires eSA to not be used for setting up electronic B2B-collaboration.

Modifiability: It can be expected that a newly developed electronic B2B-collaboration system needs to undergo continuous change and adaptations during its lifecycle. Moreover, an eSA compliant system harmonizes inter-organizationally a heterogeneous system environment comprising of commercial software that needs to undergo regular updates. Additionally, an electronic B2B-collaboration system must be adaptable to changes in the business environment.

Portability: A system has the ability to run under different computing environments as eSourcing is enabled by a heterogeneous system infrastructure, i.e., hardware, software, or a combination of both. Hence, platform-specific considerations are encapsulated in an architecture level that enables portability by giving application software an abstract interface to its environment. In the case of an electronic B2B-collaboration system, portability must also take into account conceptual differences between collaborating parties, as business processes can be represented in different modeling notations.

Integrability: An electronic B2B-collaboration system consists of software modules that are largely developed separately and integrated at a later stage to manage the high degree of inherent complexity. Hence, integrability between the components of an eSA compliant system must be ensured in the reference architecture.

Next, the system requirements are specified for eSA that are *discernable during runtime* because their effectiveness is investigatable during an eSA facilitated setup of electronic B2B-collaboration.

Interoperability: An eSA compliant system has to be able to interoperate with information systems supporting other business functions (e.g., planning, logistics, production, external partner systems). Particularly in electronic B2B-collaboration, the heterogeneous system environment of collaborating parties can not be connected directly for reasons of business security and safety.

Performance: The computational and communicational load in electronic B2B-collaboration for the setup, enactment, and post-enactment phases is considerable. Hence, it is important to ensure that all phases of a collaboration are carried out within a desirable response time.

Security: Refers to the ability of resisting unauthorized attempts at usage and denial of service while still providing its service to legitimate users. In electronic B2B-collaboration, sensitive data is exchanged between opposing business partners. Hence, for eSA a high level of security and also trust is relevant. To address security and trust problems, several architectural strategies are possible. An authentication server may be placed between collaborating parties. Monitors may be used for inspecting and logging

network events. The communication of a system may be placed behind a firewall, and so on.

High Automation: Enterprises require electronic B2B-collaboration systems that provide a high level of automation during the setup, enactment and post-enactment phases. Hence, eSA must be a reference architecture that provides for possibilities of a high degree of collaboration automation.

Flexibility: Electronic B2B-collaboration is a highly dynamic process that involves the execution of diverse activities, the participation of diverse partners, and the exchange of diverse data [34, 35, 38, 40]. Hence, eSA must be guiding for the development of systems that allow diverse collaboration scenarios and permit the inter-organizational harmonization of heterogeneous concepts and technologies.

Usability: Refers to eSA being as reference architecture that is easy to use for developing software applications. Additionally this requirement is broken up into the following three areas [6] that are relevant for eSA. *Error avoidance* means that mechanisms are in place to prevent and anticipate common errors that occur during an electronic B2B-collaboration. Closely related is the issue of *error handling*, which is satisfied when a system helps a user to recover from errors. *Learnability* refers to how quickly users can learn using the system. For an electronic B2B-collaboration system, inter- and intra-organizational knowledge workers must conceptualize business processes and project them externally to business counterparts until a collaboration consensus is achieved. During enactment, employees slip into roles that are defined in a collaboration configuration and they need to carry out assigned tasks. During the setup, enactment, and post-enactment phases, experienced administrators must be available to intervene in cases of exception-handling escalations. Finally, an eSA compliant system must foster communications between all stakeholders of an electronic B2B-collaboration system.

Additionally, we consider *requirements on architecture*. **Completeness** is the quality of eSA comprising the components required for setting up and enacting an electronic B2B-collaboration system satisfactorily. The requirement of **feasibility** means that it should be possible to set up an electronic B2B-collaboration with eSA-compliant components. **Scalability** refers to the ability of eSA to combine more than two collaborating parties into one electronic B2B-collaboration. **Applicability** states that eSA is instrumental for guiding the development of inter-organizational collaboration applications that supports an indirect connection of internal legacy systems.

Next, the results of an ATAM-based [20] reference-architecture evaluation of eSA are presented for the requirements stated above.

6.2 Evaluation of Non-Functional Requirements

We first present which architectural styles and patterns in eSA support the non-functional requirements of Section 6.1. For the requirements in eSA that can not be adhered to with patterns and styles, we show how they are realized otherwise. Finally, we investigate how other reference architectures influence the eSA-specification. Note that not all non-functional requirements of Section 6.1 can be covered with styles and patterns. Hence, at the end of this section we show how the remaining non-functional requirements are covered.

Patterns and Styles in eSA: Architectural styles [7, 48] describe component types and their topology, the pattern of data and control interaction among the components, and informally describe their benefits and drawbacks. Architectural styles differentiate classes of designs by offering experiential evidence of how each class has been used, along with qualitative reasoning to explain why each class has certain properties. We define an architectural pattern [41] as a conceptually formulated knowledge that is technology independent. A pattern for software architecture [7] describes a particular recurring design problem that arises in specific design contexts, and presents a well-proven generic scheme for its solution. Just as with architectural styles, in eSA patterns are used for adhering to non-functional requirements.

In Table 2, an overview of the non-functional requirements is depicted. The top row lists the architectural styles and patterns that are present in eSA. In Table 2, a plus sign means a particular style or pattern supports a non-functional requirement. A minus sign means that a style or pattern does not support a requirement. Both signs are assigned based on the specifications about architectural pattern and styles literature [7, 41, 48] that indicate what non-functional requirements they cover.

			Styles			Patterns			
Category		Quality	layering	publish/subscribe	abstract-data-repository	whole-part	broker	facade	pipes-and-filters
system	design time	modifiability	+		+	+			+
		portability	+		+				+
		integrability	+		+	+			+
	runtime	interoperability	+					+	
		performance	-	+		-	+		-
		security					+	+	
		flexibility		+	+	+			+
architecture		scalability					+		

Table 2. Coverage of non-functional requirements by styles and patterns.

In eSA a *layering style* [5, 7] is used for the domains of a service consumer and service provider because it helps to structure the components of eSA into groups at a particular level of abstraction. For eSA, these abstraction levels are the external collaboration level, the conceptual level, and the internal level where legacy systems are managed and orchestrated. In eSA, strict layering is used as within a collaborating party, each level only communicates with each adjacent level. By using a layering style, eSA supports the requirements of **modifiability**, **portability**, and **integrability**. Most importantly the **interoperability** is supported as the layer style prevents collaborating parties from having to link their legacy systems directly. As a tradeoff, a layering style results in extra communication overhead between the levels, which does not support **performance**.

The trusted third party of eSA uses a *publish/subscribe style* [22] in which the data producers are called publishers and the consumers are subscribers. When a publisher submits new data, all subscribers are notified and automatically receive the data. In the trusted-third-party component the notifier forms the central component of a star topology where the publishers and subscribers are the leaves. The advantage of this style in a multi-party collaboration environment with large numbers of potential service consumers and service providers is enhanced system **performance** as the communication

overhead is reduced and additionally, the **flexibility** and **integrability** of eSA-adhering applications is supported.

With respect to the remaining way of data management in eSA, an *abstract-data-repository style* [22] is employed. This style is characterized by keeping the producers and consumers of shared data from having knowledge of each others existence and the details of their implementations. In the case of eSA, the abstract data repository style is also realized by using a layering style and by interposing an intermediary protocol between the producer and consumers of shared data items. Note, that the external level of eSA is replicated in all domains of collaborating parties and only accessible through the coordination interface component. Furthermore, the abstract data repository style requires an abstract interface to the data repository that further reduces the coupling between the data producers and consumers. With this architecture style, eSA supports the requirements **flexibility**, **modifiability**, **integrability**, and **portability**.

A *whole-part pattern* [7] is used to aggregate the parts of a business collaboration. In eSA, dedicated components exist on the external level and the internal level in the form of the global and local WFMS and rules engine. Additionally, the conceptual level differentiates modeling support for business processes and business rules. Within the global and local WFMS, aggregating components are contained, termed the enactment monitor, conjoinment manager, and enactment manager. By using the whole-part pattern, eSA supports **modifiability**, **flexibility** and **integrability** through modularization while **performance** is not supported.

The *broker pattern* [7] is represented in eSA as a trusted-third-party component between the domains of collaborating parties. A broker is a separate component that interacts with the remainder of the architecture. Its purpose is the redirection and bundling of communicating with many collaborating parties. Hence, since the broker pattern stops parties from having to find, contact and investigate every potential collaborating party separately, **performance** is positively affected. Instead, the broker pattern centrally offers information about collaborating parties that can conveniently be searched. The best candidate for service consumption or service provision may then be contacted for further collaboration negotiations. In eSA, collaborating parties may use the trusted third party for submitting service requests and service offers that can be centrally searched and for which bids may be placed. Using the broker pattern in eSA enhances **scalability** as it simplifies the task for service providers and service consumers to collaborate with each other. Most importantly, the **security** requirement is supported by placing a decoupled component between business domains with which they must register and that is used for enhancing the trust between collaborating parties.

The already mentioned coordination-interface component on the external level of eSA realizes the *facade pattern* [12]. That way a unified interface is offered to a collaborating counterpart for accessing a set of interfaces of a subsystem, namely the replicated components of the external level. Hence, this way the **interoperability** between business parties is supported and the **security** in a collaboration is enhanced as the legacy systems are shielded behind the facade of the coordination interface.

On the conceptual level of eSA a *pipes-and-filters pattern* [7] is used for establishing communication channels between the external and the internal level via the conceptual level. This pattern provides a structure for processing streams of data while each pro-

cessing step is encapsulated in filter components. Hence, data is passed through pipes between adjacent filters from the external level to the internal level and vice versa. With the pipes-and filters pattern, eSA supports **flexibility**, **modifiability**, **integrability**, and **portability**. However, pipes and filters for data passing have a negative effect on the collaboration **performance**.

Alternative Evaluation of Remaining Non-Functional Requirements: The eSourcing architecture comprises many components for covering the full range of setup and enactment activities of an electronic B2B-collaboration as are described in Section 4. Hence, a **high automation** of functional requirements for eSA adhering systems is ensured, with the exception of the post-enactment phase, which still requires deeper scientific exploration. As eSA components are designed based on collaboration scenarios for the setup of electronic B2B-collaborations [34, 35, 38], the **completeness** requirement is adhered to. This claim is supported by Section 5.3 where the functional-requirement coverage is presented. The eSourcing architecture is **scalable** because in [35] it is shown that the underlying concept of eSourcing allows for a collaboration of one service consumer with many service providers. Hence, eSA adhering application systems enable many parties to engage in a B2B-collaboration.

In the CrossWork project, an architecture for a modular system infrastructure was developed [31] for the automated setup of electronic B2B collaboration. That architecture in CrossWork represents a subset of eSA and has been implemented with a modular infrastructure as a proof-of-concept prototype for the CrossWork exploitation phase. Hence, the CrossWork prototype shows the **feasibility** of eSA. Unfortunately, currently no commercial applications exist that demonstrate the **applicability** of eSA. However, the **usability** requirement is supported in eSA with the provision of verification components in the trusted third party of which implementations exist [26, 28, 29, 46, 47, 49, 50]. Additionally, usability is addressed by the setup-support component on the conceptual level that comprises a validator from test-running internally modeled processes. In [32, 33] describes an implementation of the validator component.

Unfortunately, with the lack of available commercial applications we can not offer empirical results about the **learnability** of an eSourcing architecture adhering application. It is predictable that business users, logistics managers, industrial managers, and so on, will be able to use the components available for finding service offers and service requests for electronic B2B-collaboration. With training, business users are expected to employ conceptual-level modelling components for business processes and rules successfully. However, for applying the verification and validation applications for checking eSourcing configurations the involvement of specialist inter- and intra-organizational knowledge workers. Next follows an explanation about the architectural styles and patterns that cover the remaining non-functional requirements.

We explain how eSA borrows features from other reference architectures. First, the **Workflow Reference Model** [51] and the **Reference Architecture for Workflow Management Systems** [15] is contained in eSA for the global and local workflow management systems. The **E-Contracting Reference Architecture** [4] is contained as the contracting client in the eSourcing middleware needs to be realized for eSA-compliant application systems.

6.3 Results of the ATAM Workshops

With an ATAM-based evaluation of eSA, the objective is pursued to check if the requirements stipulated in Section 4 are satisfied. Additionally, eSA is checked for sensitivity and tradeoff points, risks and non-risks. That way the strengths and weaknesses of eSA, potential pitfalls and bottlenecks are detected that need to be considered for the development of eSA-complying application systems.

The ATAM evaluation was conducted in several workshop sessions with five experts with a research focus on software engineering and electronic business collaboration. The ATAM evaluation of eSA was conducted with the objective to find risks, sensitivity and tradeoff points, and non-risks that result in an updated specification that constitutes eSRA (see Section 7). First, the experts collaboratively discussed eSA in the workshops and posed questions to explore if all requirements are fulfilled. Appendix A.1 lists these questions and assigns them to the requirements. These initial discussions of non-functional requirements resulted in a subset where the participants agreed further investigation was required. Hence, the list of attribute-characterizing questions of Table 3 does not comprise portability, interoperability, completeness, feasibility, applicability, as the workshop participants determined these requirements are well realized in eSA.

Secondly, the set of questions resulted in a so-called utility-tree (see Appendix A.2) comprising a refinement of the non-functional requirements with sub-factors in the context of eSA. In this step, the number of investigated requirements is further reduced in the utility tree of Table 4 where integrability, high automation, usability, and scalability are not contained. Finally, for each sub-factor of the remaining non-functional qualities, eSA-specific scenarios (see Appendix A.3) was found and the most relevant scenarios were detected for further exploration.

Out of the four chosen highest ranked scenarios in the utility tree, three are related to the usability and one to the security requirement of eSA-complying application systems. The amount of chosen scenarios for usability can on the one hand be explained by its importance for the adoption of eSA-compliant systems by users, and on the other hand by the need of users to handle the complex situation of setting up and enacting electronic B2B-collaborations with the support of tools that have well designed user interfaces. Concretely, Table 4 in Appendix A.2 shows that usability scenarios are related to the sub-factors error avoidance, error handling, and verification. Their importance is justified by the fact that electronic business collaborations that are not checked during the setup and enactment phase and where occurring mistakes can not be handled quickly, will result in loss of time and money, unsatisfied customers, penalty payments, and so on.

The fourth highly ranked scenario focuses on security and addresses specifically the sub-factor of security termed trust management. In electronic business collaboration this sub-factor is important because it is problematic to know in such anonymous markets how trustworthy a potential collaboration party is. Hence, it is important to have mechanisms and tools available that on the one hand permit an evaluation of potential business partners before engaging in a collaboration, and on the other hand to keep track of the performance of individual business partners during setup and enactment time.

Note that the evaluation results of eSA are applicable for the final specification of eSRA that is presented in Section 7. Hence, in summary for eSRA, the detected risks, sensitivity and tradeoff points that result from the eSA evaluation, for usability focus on supporting the user during the setup and enactment phase of an electronic business collaboration. Simultaneously it must be ensured that business internalare not disclosed to the counterpart. The same visibility problem exists for tools that verify different perspectives of a business collaboration.

For trust management, the risks and sensitivity points reveal a lack in the initial eSA-specification [35, 39] of components for collecting trust related information about collaboration parties that also include information about reputation and conflict resolution . In Figure 7 of the eSRA specification, these additional components are depicted in the contracting client and the trusted-third-party component. The components represent a minimum in eSRA for covering trust management [17, 43–45] for which many more mechanisms exist. However, for a complete trust-management coverage it is essential to also consider the way how collaborating parties agree on forming a temporary relationship in which the behavior rules and constraints are set. Such a relationship between collaboration parties has a lifecycle with the stages of an initiation, a set of stages that is characterized by events such as a party being eliminated or leaving and to be replaced by alternative parties, changes of behavior rules and constraints, and so on. Eventually, the temporary business relationship reaches the end of its lifecycle when there is no further need to carry out new eSourcing transactions. For this type of lifecycle the so-called eCommunities [23] concept may be utilized together with its proof-of-concept prototype called Pilarcos. Hence,in future research we are planning to investigate how eSRA can be integrated with Pilarcos so that trust management in electronic business collaboration may further strengthened compared to the current provisions.

With respect to tradeoff points, the ATAM-evaluation could conclude that primarily the relationship between the performance, usability, and modifiability requirements need to be taken into consideration during the development of eSRA-complying systems. Performance is important because users need an acceptable response time in an electronic business collaboration. However, performance is negatively affected by elaborate tools that ensure the usability of an eSRA-compliant system. Also modifiability ensured by patterns like a layer architecture, whole-part decomposition, pipes and filters, or abstract data repositories results in an overhead that is detrimental for performance. In Table 8, all details related to scenarios risks, sensitivity and tradeoff points are contained.

In summary, the evaluation of the initial eSA-specification [35, 39] shows that the highest level (see Figure 6) is sound. However, some changes are required for the second refinement level (see Section 7). Concretely, we extended the initial eSRA-specification with additional components for reputation and identity management (see Figure 7) and with coordinator components between the global rules engine and the global WFMS (see Figure 7) and the local rules engine and local WFMS (see Figure 10). The third refinement level of the initial eSRA-specification remains unaffected by results of the evaluation.

For implementing eSRA-compliant application systems, the risks, sensitivity and tradeoff points resulting from the eSA evaluation, reveal that emphasis must be put on

the development of graphical user interfaces (GUI) that facilitate the adoption process by collaborating companies. The GUIs must ensure that no business internals are revealed to the collaborating counterparts. Furthermore, verification and evaluation tools must ensure the correctness of an eSourcing configuration before the enactment phase. Since such verification and evaluation tools are computationally expensive, the performance of eSRA-compliant systems may be affected. In the following section the updated eSRA specification is presented that reflects the eSA-evaluation results.

Next, we present an updated specification of eSA that incorporates updates for shortcomings that the ATAM evaluation revealed.

7 Specification of eSRA

As pointed out in the introduction of this paper, the objective is to put forward the reference architecture eSRA. In the sequel, the first and second refinement levels of eSRA are presented. We omit repeating covering the first architecture level of Section 5.2 as the ATAM evaluation resulted in no need for modifications.

7.1 Second Detail-Level of the eSourcing Reference Architecture

Each component of the reference architecture depicted in Figure 6 is further refined. The first refinement in Figure 7 covers all components that are located on the external level, namely the eSourcing middleware, and the trusted third party, which is visualized by light gray shading. We refine dark gray shaded components in the sequel of this paper. In all figures of this subsection, the refined components of focus are depicted with their exchanges to bordering components.

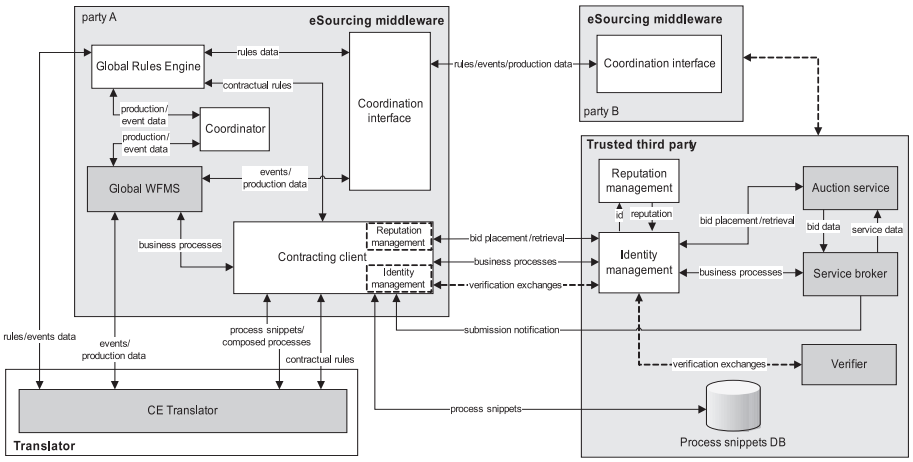


Fig. 7. External-level collaboration.

In Figure 7, the eSourcing middleware of one collaborating party is depicted. The eSourcing counterpart contains the same second-level components. Figure 7 shows the components of the trusted-third-party data exchanges with neighboring components belonging to the eSourcing middleware.

In the trusted-third-party component, most interaction with the eSourcing middleware takes place through the identity-management component that uses the reputation-management component to ensure no untrustworthy services are exchanged. We refer to [4] for more details about trust management in the eSRA-contained E-contracting Reference Architecture.

The eSourcing middleware contains several refining components. The contracting-client component provides support for the management of an e-contracting process. Concretely, the contracting client semi-automatically assembles services by using process snippets that are stored in a corresponding database of the trusted third party. That way the process snippets are available between collaborating organizations.

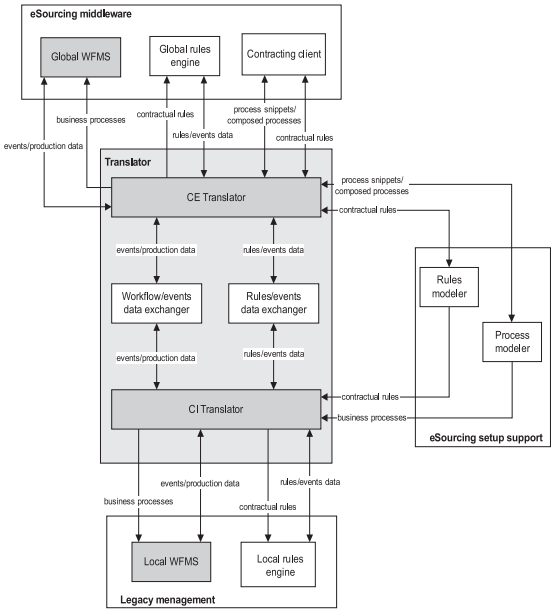


Fig. 8. Translating between external and internal level.

Depending on whether a collaborating party slips into the role of a service consumer or service provider, the contracting client submits or retrieves either service offers or a service requests respectively from a service broker. If a submitted service contains the definition of a concerned party, a submission notification is sent out from the service broker. If several parties are interested in the same service, bids need to be placed with the auction service.

The latter component relates the bid data with services stored in the service broker. When an eSourcing configuration is established, the collaborating parties send their in-house processes and provider process to a verifier component for testing the correct termination, i.e., the soundness (see [2, 21] for details) of the overall eSourcing configuration. The verification results are returned to the collaborating parties. By having a trusted third party perform the verification, the collaborating parties do not have to disclose their internal business details to each other.

When an eSourcing configuration is established, the contracting client distributes the business rules and the processes contained in the contract to the global rules engine and the workflow management system (WFMS) respectively. In order to synchronize the global WFMS and global rules engines in the eSourcing-middleware components of other collaborating parties, events-, production-, and rules data are communicated via a coordinator component, e.g., the specification of a product. The global WFMS and rules engine also exchange production-, and event data with each other.

The contracting client sends process snippets and composed processes and contractual rules to the translator. The latter component translates the process snippets and composed processes and contractual rules for the heterogeneous system environment that exists on lower internal levels of a collaborating party. The global WFMS and rules engine send data to the translator component that is depicted as light gray shaded in Figure 8. The translator contains two main translator components for translating data between the external, conceptual and internal level.

The CE-translator component of Figure 8 translates data from the internal and conceptual to the external level and vice versa. The component is connected with the rules and process modelers of the eSourcing-setup-support component. The relationships between the CE-translator and components contained in the eSourcing middleware are explained above.

Two components exchange data between the CE-translator and CI-translator, namely the workflow/events data exchanger and the rules/events data exchanger. The exchanged data must be equipped with information about where data needs to be routed to. For example, several instances of WFMS and rules engines on the external and internal level may enact several instances of different eSourcing configurations. On the internal level, several web services wrap legacy systems to which exchanged data is routed.

The CI-translator component translates data between components of the conceptual and internal levels. From the data-exchanger components, events-, rules-, and production data are translated bi-directionally to the local WFMS and rules engine on the internal level. Furthermore, the CI-translator receives contractual rules from the rules modeler and business processes from the process modeler. These rules and processes are translated to the local WFMS and rules engine on the internal level.

The eSourcing-setup-support component of Figure 9 is located on the conceptual level of eSRA (see Figure 6). The component has two core functions, namely modeling business rules and processes, and composing workflows that are on the one hand evaluated and on the other hand verified for correct termination. Thus, the rules modeler and the process modeler are responsible for the first function for which they are supported by a pattern knowledge base. In [34, 41], the pattern knowledge base is presented in further detail. The second function is related to the workflow-composition component.

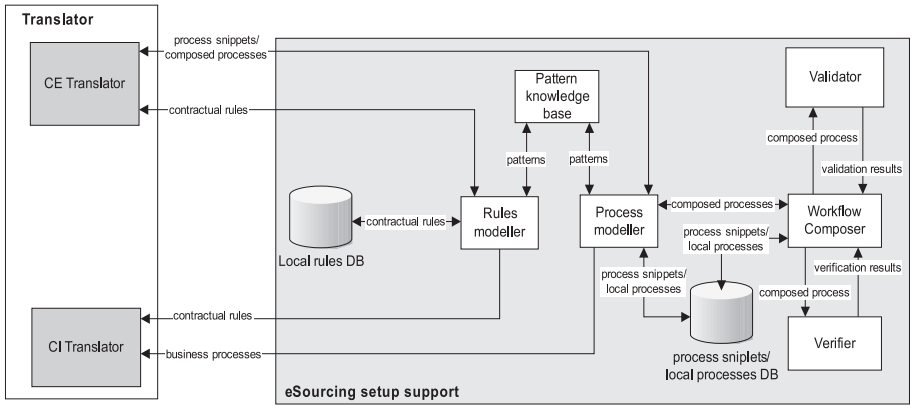


Fig. 9. Setup functionality.

For composition [10], process snippets or local processes are taken from a dedicated database, which are supplied by the process modeler.

A composed workflow is either a process of a service consumer or a service provider and checked internally in two ways. The internal checks always need to take place independent of what business-process content is projected to the external level. Provided the trustworthiness of the collaborating parties is ensured, then external checks by the trusted third party are only necessary when merely the service interfaces are projected without additional process content, i.e., when black-box projection is performed. Otherwise external checks are not necessary when the service provider performs a total business-process projection to the external level. In [35] more details are contained about such compositionality of services. However, note that external checks by the trusted third party are always required if the trustworthiness of projected business-process contents to the external level can not be assured.

With respect to checks of control flow, first correct termination is verified, e.g., by the tool Woflan [49] for which the process needs to be mapped to a place/transition net. Woflan checks for structural conflicts, i.e., deadlocks or lack of synchronization. Thus, if the process is verified to terminate correctly, it conforms to the notion of soundness [2]. Secondly, the processes of the service consumer or service provider needs to be verified for other conflicts, e.g., data-flow or resources such as humans or machines.

It is desirable to have verification tools for several workflow related perspectives, e.g., data-flow and resources. Additionally, it is essential to validate the in-house process of a service consumer and provider processes of an eSourcing configuration. Among other aspects, such a validation is meaningful for testing how the different perspectives fit together for workflow enactment, e.g., the correct functioning of the web services that are orchestrated by the processes.

Figure 10 visualizes a second-level refinement of the legacy management component. In it, a local WFMS and rules engine constitute the core components. These components exchange data between each other and are instrumental for coordinating legacy

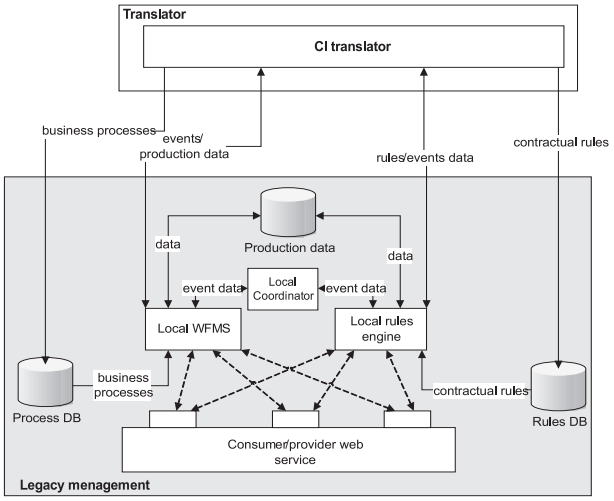


Fig. 10. Connecting to internal legacy systems.

systems. The business rules and processes that are enacted by the WFMS and rules engine are translated down to the internal level by the CI-translator. For enactment, the local WFMS and rules engine use a production database. Furthermore, to coordinate the enactment on an internal level and external level, the local WFMS and rules engine communicate events, rules, and production data bi-directionally.

7.2 Third Detail-Level of eSourcing Reference Architecture

In this subsection, the dark-gray shaded eSRA components of Section 7.1 are further refined according to the principles of functional decomposition. The refinement of the CE-translator in Figure 11 depicts a CE projector component that is performing projections between the conceptual and external levels. To perform that function, the CE projector uses a rules database.

Figure 11 shows several bidirectional arcs to the CE-projector. The rules- and process-modeler components exchange contractual rules and process snippets and composed processes via the CE projector with the contracting client on the external level. The global rules engine receives contractual rules from the CE projector through which rules and events data is exchanged via the rules- and events data exchanger down to the local rules engine on the internal level. Figure 11 depicts a detailed exchange between the CE projector and components of the global WFMS. The enactment engine receives contractual spheres from the service consumer or provider respectively. During enactment, data is exchanged between the enactment monitor and the conjoinment monitor, which is explained below and depicted in Figure 12. The latter two components exchange events and production data via the CE projector and the workflow/events data exchanger down to the local enactment monitor and conjoinment monitor that are located on the internal level of the reference architecture.

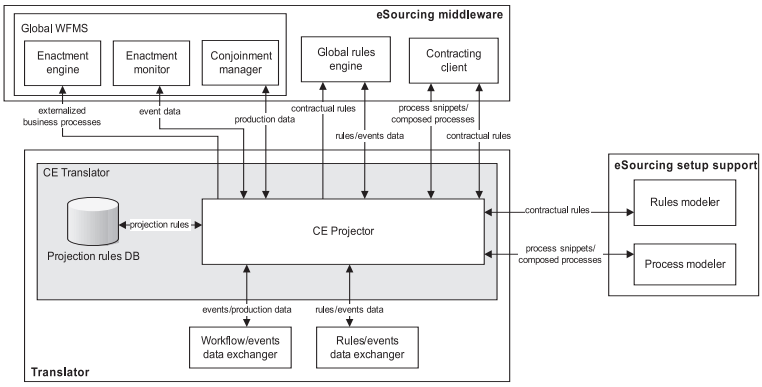


Fig. 11. The CE-translator in detail.

In Figure 12, the global WFMS component of the eSourcing middleware is depicted as a refinement. It shows an enactment engine for the collaborating party's business processes that are delivered from the CE-translator. Event and production data is created during enactment and also needed for enactment and therefore stored and retrieved from dedicated databases.

In order to support the concept of eSourcing, Figure 12 shows an enactment-monitor component and conjoinment-monitor component. Concretely, the enactment monitor is responsible for allowing the service consumer to monitor the enactment progress of service provision. In Section 3.4, the business aspects are specified that the enactment-monitor component supports. Likewise, the conjoinment-manager component supports the conjoinment options specified in Section 3.4. Both the enactment monitor and the conjoinment manager exchange production and event data with components in the domain of the collaborating party via the coordination interface. Furthermore, production and event data is communicated to the internal level via the CE-translator to coordinate local components.

The refinement of the CI-translator in Figure 13 depicts a similar setup as for the CE-translator. However, the information exchange to neighboring components differs. The CI-translator contains a CI-projector component that projects information between the conceptual and internal level. To do so, a projection-rules database is exchanging rules with the CI projector. The CI projector receives contractual rules from the rules modeler, and business processes from the process modeler. The contractual rules are delivered to the local rules engine of the internal level. Furthermore, the business-process specifications are also delivered to the internal level where a process database stores them until the local WFMS loads the processes for enactment. To coordinate the local WFMS and rules engine with corresponding components on the external level, the CI-projector transfers production, rules, and events data between the internal and external levels of the reference architecture.

The internal level refinement of Figure 14 shows a setup that is comparable to the global WFMS of Figure 12. The local WFMS contains an enactment engine that

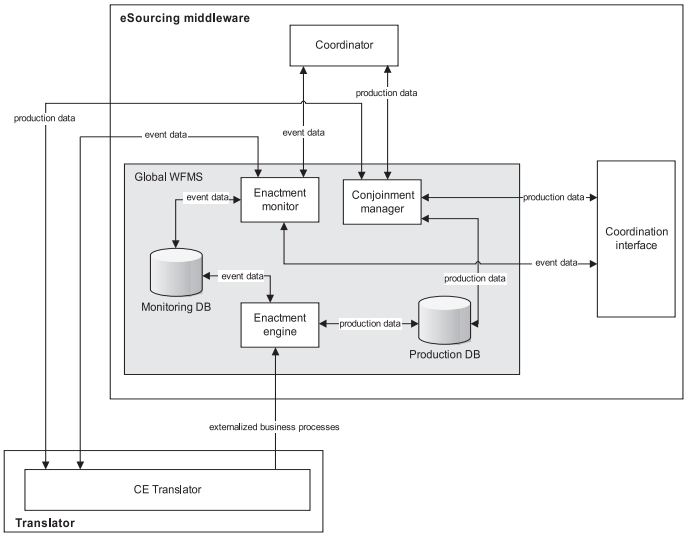


Fig. 12. The global WFMS in detail.

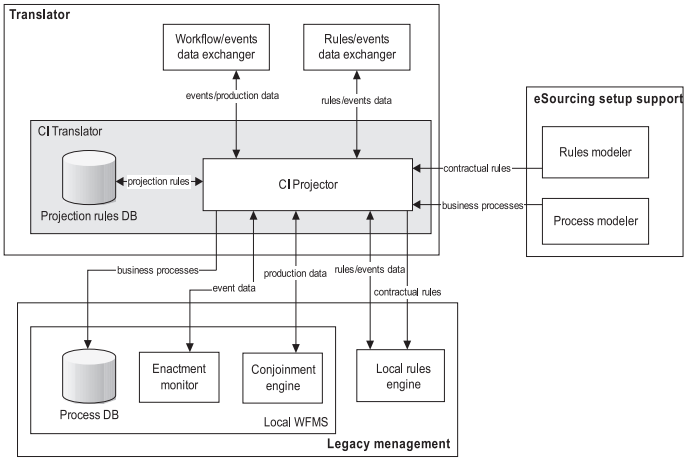


Fig. 13. The CI-translator in detail.

receives business processes from the process database. Production data that is produced and consumed during process enactment is exchanged with the production-data database. Event data is exchanged with the local rules engine that carries out contractual rules. Furthermore, the enactment engine exchanges data with ports for the coordination of legacy systems. To coordinate the local enactment progress with the external level, production data and event data are exchanged with the conjoinment manager and the enactment monitor respectively. The latter two components exchange events- and production data via the CI-translator with the equally named components located on the external level.

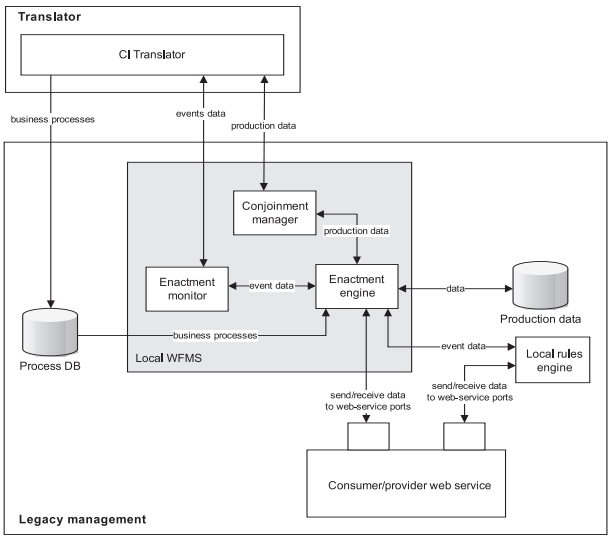


Fig. 14. The local WFMS in detail.

The service-broker refinement within the trusted third party of Figure 15 reveals a service-library database that stores business processes of collaborating parties via the template search engine. The latter component exchanges business-process specifications with the contracting client of the eSourcing middleware that is located on the external level of the collaborating parties. Furthermore, the template search engine exchanges data with the bid-manager component of the auction service. The notifier component checks business-process specifications that are stored in the service library for data about a collaborating party that needs to be informed. If such facts are defined, the notifier informs the specified contracting client of the respective parties about the submission of a projected consumer sphere or provider process. Consequently, informed parties check the stored business-process specifications and either engage in a bidding procedure or commit to the externalized business process by directly responding with committing a separate process to the trusted third party.

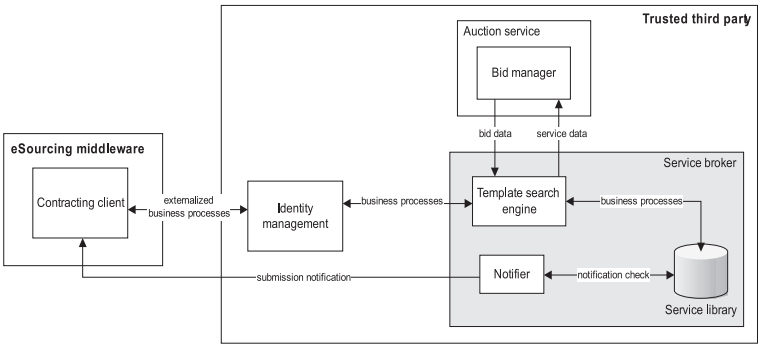


Fig. 15. The service broker in detail.

The refined auction service of the trusted third party is depicted in Figure 16. In the auction service component, the contained bidding library stores bids that are committed and retrieved by a bid manager. This component is communicating with the contracting-client component that places and retrieves bids from the bidding library. As described earlier, the bid manager is exchanging bid- and service data with the template-search-engine component of the service broker.

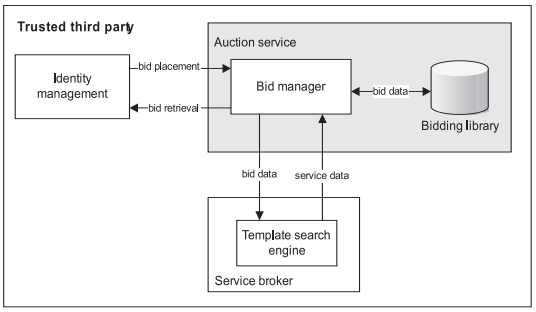


Fig. 16. The auction service in detail.

Finally, the last component of the trusted third party is the verifier. In [35], a verifier architecture is presented that is suitable for the trusted third party. In this architecture, the business processes of the collaborating parties are flattened to a P/T-net and consequently verified for correct termination and inheritance relations.

In Figure 17, a process-communicator component receives a request from the contracting client belonging to the domain of a collaborating party to perform a verification of a created eSourcing configuration. The process communicator requests the conceptual-level processes of all collaborating parties and the contractual spheres from

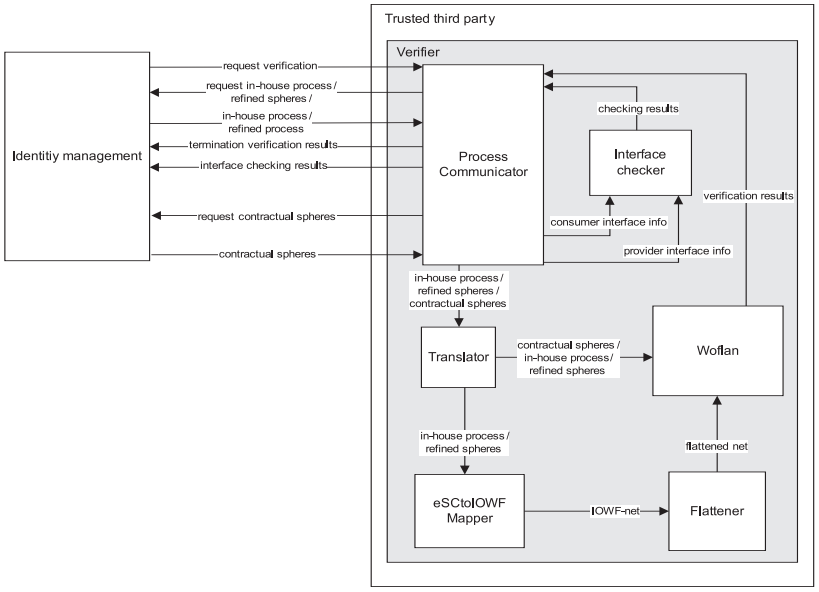


Fig. 17. The verifier component in detail.

the eSourcing middleware. Next, the collected in-house process, the provider spheres, and the contractual spheres are delivered to a translator that converts the processes into a format the eSCtoIOWF-mapper component and Woflan can process. The first component delivers the resulting IOWF-net to a flattener component that creates a net, which Woflan verifies for soundness and projection inheritance. For the latter verification type the in-house process is compared with the flattened P/T-net. In [35] further details about P/T-net details are contained.

8 Conclusion and Future Work

In this paper we evaluate an earlier specified eSourcing architecture eSA for systems that support the setup and enactment of electronic B2B-collaborations. The evaluation commences with business drivers for eSourcing from which we deduce functional and non-functional requirements. We use the ATAM-method for evaluating to which extent the initial architecture specification adheres to the requirements for electronic B2B-collaboration systems. The results of the evaluation enter an updated specification that describes the eSourcing Reference Architecture eSRA.

eSRA is guiding for software developers who design and implement information systems for supporting the automated setup and enactment of electronic B2B-collaboration. The risks and sensitivity points that were discovered during the ATAM-evaluation of eSRA, point out the relevance of verification tools for the setup and enactment of electronic B2B-collaboration and for the introduction of trust-management components.

At the same time the collaborating parties must be able to protect their business secrets and the overall performance of an eSRA compliant system must not limit B2B-collaboration. Besides the need for computationally expensive verification tools, the layer architecture, pipes and filters, and whole-part decompositions in eSRA create performance bottlenecks. The discovered risk and sensitivity points result in additional components in eSRA located in the contracting-client and trusted-third-party to cover trust management. Finally, the tradeoff points for eSRA show that good usability and modifiability have a negative influence on performance.

In detail, the results from the ATAM evaluation show several important issues for implementing eSRA-compliant applications. Firstly, a need for finding verification tools for the setup and enactment phases of an electronic B2B-collaboration is a scientific challenge. Such verification tools must be developed for several collaboration perspectives, e.g., control flow, data flow, resource management, transaction management, and so on. The difficulty is that these tools must have strong graphical user support that allows an instantaneous detection of errors while at the same time no business secrets should be revealed to the collaborating counterpart.

Secondly, the adoption of an eSRA-compliant application system for B2B-collaboration also triggers a change in corporate culture that an eSRA application requires. An organization must first introduce an awareness of intra and inter-organizational business process collaboration, think about the business rules it wants to employ, and shift to an electronic way of managing contracts. Such multiple shifts in corporate activities require a restructuring that leads to political tensions inside an organization. Hence, an eSRA application introduction may be made impossible on the one hand by such political tensions and on the other hand be impossible because users with the required skills are not available for carrying out electronic B2B-collaboration.

Several directions for future work exist. Firstly, for ensuring trust management dedicated components are adopted in eSRA. However, since trust-management is an ongoing research issue, several options for component refinement must be explored. Secondly, currently the post-enactment phase of an electronic B2B-collaboration is out of scope for eSRA. The post-enactment phase will be clearer with more results from the development of an e-business transaction concept for electronic B2B-collaboration that incorporates exception handling and compensation. Such results

Acknowledgements

We thank the experts of the ATAM workshops for their participation in the many eSA evaluation sessions, namely Juha Gustafsson, Joni Niemi, and Jukka Viljamaa. Their detailed and thorough exploration of eSA was essential for generating evaluation results that have lead to a deeper understanding of the reference architecture eSRA.

This research was partly conducted in the EU-FP6 research project CrossWork and partly in SOAMeS (Service Oriented Architecture in Multichannel e-Services). The latter project is funded by Finnish Funding Agency for Technology and Innovation, VTT, Elisa Oyj, Kesko Oyj, Metsäteho Oy, and TietoEnator Processing & Network Oy.

References

1. IBM MQSeries workflow. http://www-4.ibm.com/software/mqseries/workflow.
2. W.M.P. van der Aalst. The Application of Petri Nets to Workflow Management. *The Journal of Circuits, Systems and Computers*, 8(1):21–66, 1998.
3. G. Alonso, SU. Fiedler, C. Hagen, A. Lazcano, H.Schuldt, and N. Weiler. WISE: business to business e-commerce. In *Proc. of the 9th International Workshop on Research Issues on Data Engineering*, pages 132–139, Sydney, Australia, 1999.
4. S. Angelov. *Foundations of B2B Electronic Contracting*. Dissertation, Technology University Eindhoven, Faculty of Technology Management, Information Systems Department, 2006.
5. L. Bass, P. Clements, and R. Kazman. *Software Architecture in Practice*. Addison-Wesley, 1998.
6. P.O. Bengtsson. *Architecture-Level Modifiability Analysis*. PhD thesis, Department of Software Engineering and Computer Science, Blekinge Institute of Technology, Sweden, 2002.
7. F. Buschmann, R. Meunier, H. Rohnert, P. Sommerlad, and M. Stal. *Pattern-Oriented Software Architecture: A System of Patterns*. Chichester, UK: Wiley, 1996.
8. P. Clements, R. Kazman, and M. Klein. *Evaluating Software Architectures: Methods and Case Studies*. Addison Wesley, 2002.
9. T.J. Dolan. *Architecture Assessment of Information-System Families*. PhD thesis, Department of Technology Management,, Eindhoven University of Technology, The Netherlands, 2002.
10. R. Eshuis, P. Grefen, and S. Till. Structured service composition. In S. Dustdar, J. Fiadeiro, and A.P. Sheth, editors, *4th International Conference, BPM 2006*, volume 4102 of *Lecture Notes in Computer Science*, pages 97–112, Vienna, Austria, September 2006. LNCS Springer.
11. R. Eshuis and A. Norta. Constructing process views for service outsourcing. In S. Ossowski S.Y. Shin, editor, *Symposium Proc. of the 2009 ACM Symposium on Applied Computing (SAC)*, pages 1615–1616. ACM, 2009.
12. E. Gamma, R. Helm, R. Johnson, and J. Vlissides. *Design Patterns: Elements of Reusable Object-Oriented Software*. Professional Computing Series. Addison Wesley, Reading, MA, USA, 1995.
13. P. Grefen. Service-oriented support for dynamic interorganizational business process management. In M. Papazoglou D. Georgakopoulos, editor, *Service Oriented Computing*, pages 83–110. MIT Press, 2008.
14. P. Grefen, H. Ludwig, and S. Angelov. A Three-Level Framework for Process and Data Management of Complex E-Services. *International Journal of Cooperative Information Systems*, 12(4):487–531, 2003.
15. P. Grefen and R.R. de Vries. A reference architecture for workflow management systems. *Data & Knowledge Engineering*, 27(1):31–57, 1998.
16. Y. Hoffner, H. Ludwig, C. Gülcü, and P. Grefen. Architecture for Cross-Organizational Business Processes. In *Procs. 2^{nd} Int. Workshop on Advanced Issues of E-Commerce and Web-Based Information Systems*, pages 2–11, Milpitas, CA, USA, 2005.
17. A. Jøsang, R. Ismail, and C. Boyd. A survey of trust and reputation systems for online service provision. *Decision Support Systems: Emerging Issues in Collaborative Commerce*, 43(2):618–644, March 2007.
18. R. Kazman. *CBAM: Cost Benefit Analysis Method*. http://www.sei.cmu.edu/architecture/cbam.html, 2003.
19. R. Kazman, L. Bass, G. Abowd, and M. Webb. Saam: A method for analyzing the properties software architectures. In *Proc. of the 16th International Conference on Software Engineering, Sorrento, Italy*, pages 81–90, 1994.

20. R. Kazman, M. Klein, and P. Clements. *ATAM: Method for architecture evaluationevaluation: ATAM - Architecture Trade-off Analysis Method report*. http://www.sei.cmu.edu/ata/ata_method.html, 2002.
21. E. Kindler and W.M.P. van der Aalst. Liveness, Fairness, and Recurrence. *Information Processing Letters*, 70(6):269–274, June 1999.
22. M. Klein and R. Kazman. Attribute-based architectural styles. *TECHNICAL REPORT CMU/SEI-99-TR-022 ESC-TR-99-022*, 1999.
23. L. Kutvonen, J. Metso, and T. Ruokolainen. Inter-enterprise Collaboration Management in Dynamic Business Networks. In R. Meersman and Z. Tari, editors, *On the Move to Meaningful Internet Systems 2005: CoopIS, DOA, and ODBASE*, volume 3760 of *Lecture Notes in Computer Science*, page 593611, Agia Napa, Cyprus, October 2005. LNCS Springer.
24. N. Lassing. *Architecture-Level Modifiability Analysis*. PhD thesis, Free University Amsterdam, 2002.
25. A. Lazcano, H. Schuldt, G. Alonso, and H Schek. WISE: Process Based E-Commerce. *IEEE Data Engineering Bulletin*, 24(1), 2001.
26. N. Lohmann. *BPEL2oWFN: Translating BPEL Processes into Open Workflow Nets*. http://www.gnu.org/software/bpel2owfn/, 2006.
27. L.A. Maciaszek. *Requirements Analysis and System Design. Developing Information Systems with UML*. Addison Wesley, 2001.
28. P. Massuthe, W. Reisig, and K. Schmidt. An operating guideline approach to the soa. Ohrid, Republic of Macedonia, 2005.
29. P. Massuthe and D. Weinberg. *Fiona*. http://www.informatik.hu-berlin.de/top/tools4bpel/fiona, 2006.
30. N. Mehandjiev and P. Grefen. Crosswork: Internet-based support for process-oriented instant virtual enterprises. *IEEE Internet Computing*, 2010. to appear.
31. N. Mehandjiev, P. Grefen, I.D. Stalker, H. Eshuis, K. Fessl, and G. Weichhart. Designing a modular infrastructure for exploratory integration of interoperability approaches. In *Enterprise Interoperability: New Challenges and Approaches*, pages 427–440. Springer-Verlag, 2007.
32. A. Norta. XRL/flower Home Page. http://is.tm.tue.nl/research/xrl/flower.
33. A. Norta. Web supported enactment of petri-net based workflows with XRL/Flower. In J. Cortadella and W. Reisig, editors, *Proc. of the 25th International Conference on the Application and Theory of Petri Nets 2004*, number 3099 in Lecture Notes in Computer Science, pages 494–503, Bologna, Italy, 2004. Springer Verlag, Berlin.
34. A. Norta. *eSourcing: electronic Sourcing for business to business*. http://www.cs.helsinki.fi/u/anorta/research/eSourcing/, 2007.
35. A. Norta. *Exploring Dynamic Inter-Organizational Business Process Collaboration*. PhD thesis, Technology University Eindhoven, Department of Information Systems, 2007.
36. A. Norta, editor. *Exploring Dynamic Inter-Organizational BusinessProcess Collaboration: Privacy Protecting Concepts for Choreographing eSourcing in B2B with Service-Oriented Computing*. VDM, 2008.
37. A. Norta and R. Eshuis. Specification and Verification of Harmonized Business-Process Collaborations - Preprint Version. Accepted for publication in the journal of Information Systems Frontier, University of Helsinki, Finland, 2009.
38. A. Norta and P. Grefen. A Framework for Specifying Sourcing Collaborations. In Jan Ljungberg and Bo Dahlbom, editors, 14^{th} *European Conference on Information Systems: Grand Challenges*, pages CD–ROM, Gothenburg, Sweden, 2006. IT-University Gothenburg.
39. A. Norta and P. Grefen. Developing a Reference Architecture for Inter-Organizational Business Collaboration Setup Systems. BETA Working Paper Series, WP 170, Eindhoven University of Technology, Eindhoven, 2006.

40. A. Norta and P. Grefen. Discovering Patterns for Inter-Organizational Business Collaboration. *International Journal of Cooperative Information Systems (IJCIS)*, 16:507 – 544, 2007.
41. A. Norta, M. Hendrix, and P. Grefen. A pattern-knowledge base supported establishment of inter-organizational business processes. In R. Meersman and Z. Tari, editors, *On the Move to Meaningful Internet Systems 2006: CoopIS, DOA, and ODBASE*, volume 4277 of *Lecture Notes in Computer Science*, page 834843, Montpellier, France, October 2006. LNCS Springer.
42. IBM Research. Crossflow architecture description, Technical report, ESPRIT Crossflow EP 28653, 1999.
43. S. Ruohomaa and L. Kutvonen. Trust management survey. In *Proceedings of the iTrust 3rd International Conference on Trust Management, 23–26, May, 2005, Rocquencourt, France*, volume 3477 of *Lecture Notes in Computer Science*, pages 77–92. Springer-Verlag, May 2005.
44. S. Ruohomaa and L. Kutvonen. Making multi-dimensional trust decisions on inter-enterprise collaborations. In *Proceedings of the Third International Conference on Availability, Security and Reliability (ARES 2008)*, pages 873–880, Barcelona, Spain, March 2008. IEEE Computer Society.
45. S. Ruohomaa, L. Kutvonen, and E. Koutrouli. Reputation management survey. In *Proceedings of the 2nd International Conference on Availability, Reliability and Security (ARES 2007)*, pages 103–111, Vienna, Austria, April 2007. IEEE Computer Society.
46. K. Schmidt. Lola: A low level analyser. In M. Nielsen and D. Simpson, editors, *Application and Theory of Petri Nets, 21st International Conference (ICATPN 2000)*, volume 1825 of *Lecture Notes in Computer Science*, pages 465–474, Aarhus, Denmark, June 2000. LNCS Springer.
47. K. Schmidt. *LoLA: A Low Level Analyser*. http://www.informatik.hu-berlin.de/top/lola/doku.ps, 2004.
48. M. Shaw and D. Garlan. *Software Architecture: Perspectives on an Emerging Discipline.* Upper Saddle River, NJ: Prentice-Hall, 1996.
49. H.M.W. Verbeek, T. Basten, and W.M.P. van der Aalst. Diagnosing Workflow Processes Using Woflan. *The Computer Journal, British Computer Society*, 44(4):246–279, 2001.
50. H.M.W. Verbeek, T. Basten, and W.M.P. van der Aalst. Diagnosing Workflow Processes using Woflan. *The Computer Journal*, 44(4):246–279, 2001.
51. WFMC. Workflow reference model. Technical report, Workflow Management Coalition, Brussels, 1994.

A ATAM Results

The tables below show the main results from conducting the ATAM evaluation method [8, 20]. Hence, first questions were asked by workshop participants that resulted in a refinement of eSA's quality attributes with specific sub-factors. The latter factors were used to create a utility tree together with accompanying scenarios that were ranked by the experts. The most relevent scenarios were further specified and provided with sensitivity points, tradeoff points, risks, and non risks for eSA. Next, the tables we explain in detail.

A.1 Attribute-Characterizing Questions

The initial task of the workshop sessions with experts is to clarify the utility requirement of eSA that expresses the overall "goodness" of the system. Hence, questions are asked for establishing a better understanding of earlier determined quality attributes

In Table 3 the questions are listed on the right hand assigned to their quality attributes on the left side. The questions are further categorized by determining if they represent for eSA an external stimuli, an architectural decision, or a response. External stimuli are events that cause eSA to respond or change. Architectural decisions are the aspects of eSA that have a direct impact on achieving attribute responses. Finally, responses [8, 20] are quantities that are measurable or observable.

A.2 Utility Tree

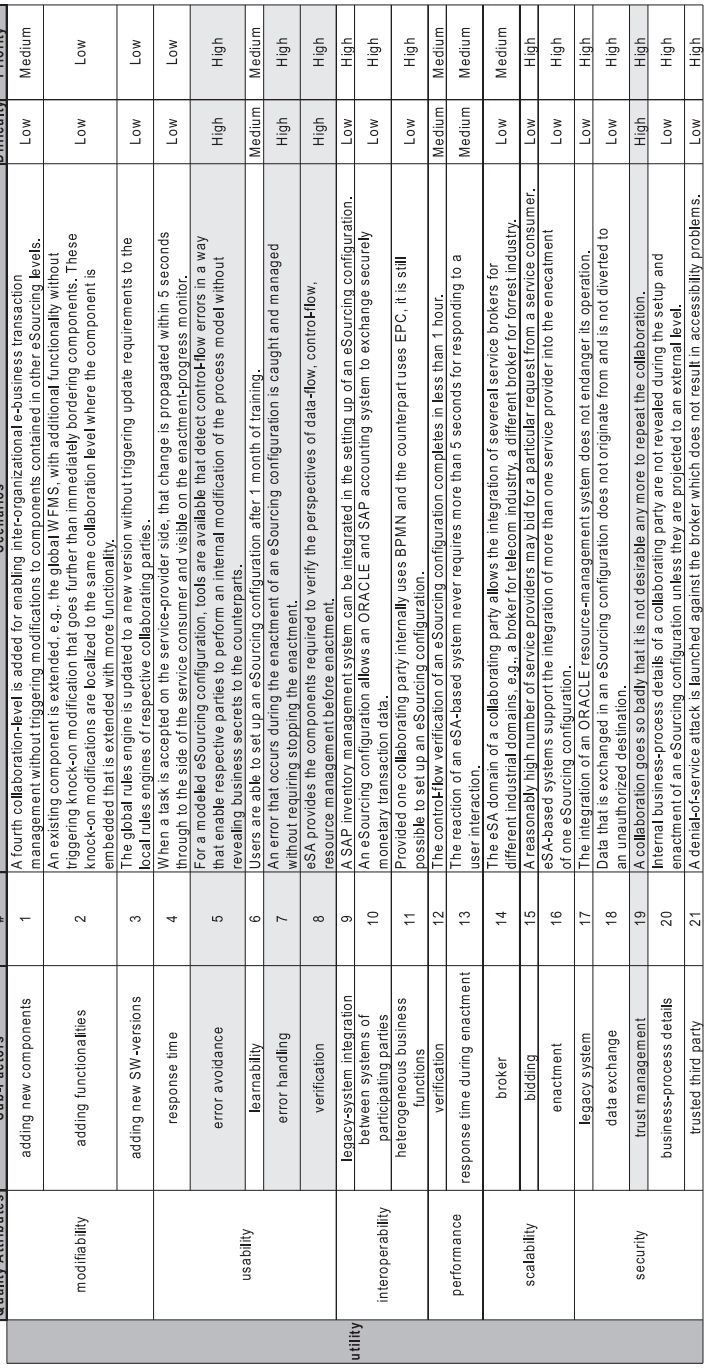
All the quality attributes and further specifying sub-factors are arranged in a utility tree that allows to organize and prioritize the goals for eSA. The utility tree is also instrumental for the creation of scenarios that are assigned to each sub-factor. These scenarios are then ranked according to the perceived difficulty and priority for eSA.

To the left of Table 4, the most important system requirement is mentioned, namely the *utility*, which is an expression for the overall "goodness" of the system. The utility is further refined by quality attributes, that are a subset of the non-functional requirements in Section 6.1. The subset of attributes results from a discussion with the ATAM-workshop participants about what should be consider for further questionings, as Table 3 shows. Quality attributes for which the workshop participants could not find questions are not considered in the ATAM evaluation as it implies eSA provides coverage. The sub-factors in Table 4 are deduced from the questions in Table 3 and refine the quality attributes. In effect, the sub-factors tell where eSA needs to be probed more deeply.

Further right of the sub-factors are scenarios listed together with the identification numbers. At the very right-hand of Table 4, the scenarios are assessed based on their perceived difficulty and the priority to realize. The gray shaded rows contain scenarios that score highly in both categories and consequently they are chosen for further investigation. In Tables 5- 7, justifications are given for the ranking of scenarios.

Quality Attributes	Stimuli	Architectural Decision	Response	Questions
high automation	x			Is it possible to define examples that state what is automatic or not automatic?
		x		Is manual interaction required?
	x			Does the legacy system influence decision (special input required)?
		x		Is it possible to perform a highly automated bidding (Agents involved, or humans involved)?
		x		What is the target degree of automation
			x	How can the degree of automation be controlled?
usability		x		Does the system cover also operational time observability and breach detection?
			x	Is there a discrepancy detection during bidding involved?
			x	How about handling errors during enactment phase?
		x		Is it possible to test run the entire eSourcing configuration?
	x			Based on which information is the decision made to eSource?
			x	When a system provides an eSourcing configuration, how much interoperability does that guarantee?
modifiability		x		Are three levels enough or are more needed?
		x		What are the expected rules of expressing yourself in each level (structuring rules)?
			x	What happens when the modeling languages are changed?
		x		What happens when a totally new component with new functionality is added?
		x		Does the architecture forbid certain extensions?
scalability		x		Does only one trusted third party component turn into a bottle neck?
		x		Is it possible to have multiple collaborating parties in an eSourcing configuration?
		x		Can multiple modeling languages be used on different levels?
	x			How many enactment parties are anticipated?
			x	Does replication imply effects on the protocols?
		x		Are dedicated components required to support replication?
			x	How does scalability affect performance?
performance			x	Is verification a bottleneck during the setup phase?
			x	How does the system ensure the response time is acceptable during enactment?
flexibility		x		To what extent does system facilitate different contracting protocols?
	x			Is multi-phase contracting supported?
	x			Is iterative contracting supported?
			x	How does eSA respond when a trusted-third parties are replicated?
			x	How does eSA respond when a contracting component is replicated?
integrability		x		Which components are envisaged that need to be integrated?
		x		How is trust management realized in eSA?
security		x		How are the legacy systems shielded from denial of service attacks?
		x		How is sensitive data exchange shielded?
		x		How are process details hidden from collaborating parties?
			x	What are the different trust levels between different eSA integration options?

Table 3. Attribute-characterizing questions.



Quality Attributes	Sub-Factors	#	Scenarios	Difficulty	Priority
utility	modifiability	adding new components	1	A fourth collaboration-level is added for enabling inter-organizational e-business transaction management without triggering modifications to components contained in other eSourcing levels.	Low	Medium
		adding functionalities	2	An existing component is extended, e.g., the global WFMS, with additional functionality without triggering knock-on modification that goes further than immediately bordering components. These knock-on modifications are localized to the same collaboration level where the component is embedded that is extended with more functionality.	Low	Low
		adding new SW-versions	3	The global rules engine is updated to a new version without triggering update requirements to the local rules engines of respective collaborating parties.	Low	Low
	usability	response time	4	When a task is accepted on the service-provider side, that change is propagated within 5 seconds through to the side of the service consumer and visible on the enactment-progress monitor.	Low	Low
		error avoidance	5	For a modeled eSourcing configuration, tools are available that detect control-flow errors in a way that enable respective parties to perform an internal modification of the process model without revealing business secrets to the counterparts.	High	High
		learnability	6	Users are able to set up an eSourcing configuration after 1 month of training.	Medium	Medium
		error handling	7	An error that occurs during the enactment of an eSourcing configuration is caught and managed without requiring stopping the enactment.	High	High
		verification	8	eSA provides the components required to verify the perspectives of data-flow, control-flow, resource management before enactment.	High	High
	interoperability	legacy-system integration	9	A SAP inventory management system can be integrated in the setting up of an eSourcing configuration.	Low	High
		between systems of participating parties	10	An eSourcing configuration allows an ORACLE and SAP accounting system to exchange securely monetary transaction data.	Low	High
		heterogeneous business functions	11	Provided one collaborating party internally uses BPMN and the counterpart uses EPC, it is still possible to set up an eSourcing configuration.	Low	High
	performance	verification	12	The control-flow verification of an eSourcing configuration completes in less than 1 hour.	Medium	Medium
		response time during enactment	13	The reaction of an eSA-based system never requires more than 5 seconds for responding to a user interaction.	Medium	Medium
	scalability	broker	14	The eSA domain of a collaborating party allows the integration of several service brokers for different industrial domains, e.g., a broker for telecom industry, a different broker for forrest industry.	Low	Medium
		bidding	15	A reasonably high number of service providers may bid for a particular request from a service consumer.	Low	High
		enactment	16	eSA-based systems support the integration of more than one service provider into the enecatment of one eSourcing configuration.	Low	High
	security	legacy system	17	The integration of an ORACLE resource-management system does not endanger its operation.	Low	High
		data exchange	18	Data that is exchanged in an eSourcing configuration does not originate from and is not diverted to an unauthorized destination.	Low	High
		trust management	19	A collaboration goes so badly that it is not desirable any more to repeat the collaboration.	High	High
		business-process details	20	Internal business-process details of a collaborating party are not revealed during the setup and enactment of an eSourcing configuration unless they are projected to an external level.	Low	High
		trusted third party	21	A denial-of-service attack is launched against the broker which does not result in accessibility problems.	Low	High

Table 4. ATAM utility tree.

Scenario	Justification	Rank	
			Difficulty
1	Since eSA comprise a part-whole pattern and a layered architecture, adding new components is not difficult.	Low	
			Priority
	As an example for an open extension issue in eSA that is not trivial, e-business transaction (eBT) management is required to safeguard B2B collaboration. For now eBT is an ongoing research topic and evolving.	Medium	
			Difficulty
2	Although component changes should remain isolated, it is realistic that minor changes need to propagate to surrounding components.	Low	
			Priority
	Given the inclusion of a layer style and a whole/part pattern, sufficient provisions are in place to not consider adding functionality as a challenge that requires high priority.	Low	
			Difficulty
3	No challenge, provided the update does not result in the adoption of rule-types that are not understood by the local rule engines.	Low	
			Priority
	Same justification as for Scenario 2.	Low	
			Difficulty
4	No challenge, provided the hardware infrastructure and the legacy systems are responding well.	Low	
			Priority
	Since it is assumed that powerful and modern hard- and software and well designed legacy systems are applied, response time is considered assured.	Low	
			Difficulty
5	Tool support for error avoidance implies a considerable research effort for powerful algorithms that support users in error avoidance. Creating a suitable GUI for pinpointing mistakes in a collaboration model is not trivial.	High	
			Priority
	Without the ability of verifying and evaluating the correctness of an electronic B2B collaboration the success of the enactment phase can not be assured. Most likely the enactment will run into problems that are followed by penalty payments, unsatisfied customers, and so on because of unintended contractual violations.	High	
			Difficulty
6	Provided the users have a background that unites business, IS, and computer-science knowledge, applying an eSA-compliant system can be learned in an acceptable time. A highly skilled consultant would be required to back up a "regular" user.	Medium	
			Priority
	If the system is so complicated that layman users can not set up and enact an electronic B2B collaboration despite the help of an assisting consultant, the adoption of eSA-compliant systems is in doubt.	Medium	
			Difficulty
7	The question is not answered how inter-organizational enactment errors should be handled in electronic B2B collaborations. Since enactment-error management should also comprise advanced inter-organizational e-business transaction management concepts that are only now scientifically investigated.	High	
			Priority
	Mechanisms must be in place that contribute as far as possible and feasibly to a successful completion of the enactment phase.	High	

Table 5. Justifying the ranking of scenarios (Part 1).

Scenario	Justification	Rank	
			Difficulty
8	Same reason as with Scenario 7.	High	
	As many perspectives of an electronic B2B-collaboration must be verifiable before enactment. control-flow, data-flow, resource perspective are a minimum.		Priority
			Difficulty
9	Any legacy system can easily be integrated if it is wrapped as a service that can be orchestrated by local WFMS and rules engines. It is essential that all legacy systems can be integrated in an electronic B2B-collaboration. Otherwise the purpose of an eSRA-compliant systems is defeated.	Low High	Priority
			Difficulty
10	On the external level the exchange of data between opposing collaborating parties is managed by a coordination-interface component that represents a facade pattern. Hence, the coordination interface can ensure secure data-transmission. Extra security is given since the legacy systems of opposing collaborating parties are only indirectly linked in an electronic B2B-collaboration.	Low	
	The data exchanges between legacy systems in an electronic B2B-collaboration must never be compromised in any situation. Any data format must be exchangeable.	High	Priority
			Difficulty
11	Different business-collaboration formulation languages are used on separate eSRA levels, which allows the projection of one language to another language on the external level. The real problem is the extent to which different business-collaboration formulation languages share semantically similar language constructs.	Low	
	It can not be assumed collaborating parties use identical concepts, notations, technologies. It is very important the differences can be inter-organizationally reconciled by an eSRA-compliant system.	High	Priority
			Difficulty
12	E.g., tools for control-flow checking require much time and computing power. With heuristics, the verification of control-flow, data-flow, resource management, transaction management, and so on, will be within an acceptable limit.	Medium	
	If verification is computationally too expensive, the results of the setup phase can not be checked and the enactment phase is in doubt before it even starts. Also ad-hoc verifications during enactment time are impossible if that is too expensive.	Medium	Priority
			Difficulty
13	Given the three levels of eSRA and the multiple components involved that may be geographically dispersed, a 5 second response time might be challenging.	Medium	
	Essential for supporting the adoption of eSRA-compliant systems by corporations. However, with powerful, modern hardware and technology and the use of well designed legacy systems, response time is not a problem.	Medium	Priority
			Difficulty
14	Broker scalability merely requires separate instantiations of the broker. Additionally, the trusted-third-party component of eSRA-compliant systems must be designed in a way to handle several brokers.	Low	
	Broker scalability is a relevant scenario that enhances the adoption of eSRA-compliant systems, however, it is easy to achieve due to the modularity of eSRA.	Medium	Priority

Table 6. Justifying the ranking of scenarios (Part 2).

Scenario	Justification	Rank	
15	Provided the server on which the broker process runs is powerful, bidding scalability is assured.	Low	Difficulty
	An eSA-compliant system must allow all potential collaborating parties to take part in bidding. Otherwise it is not ensured that the best deal is realized.	High	Priority
16	In [31], it is shown that eSourcing allows many service providers in an electronic B2B-collaboration. The whole-part pattern used in eSA supports such a scenario.	Low	Difficulty
	Real-life business collaboration is often not limited to only one service provider. Hence, eSA-compliant systems must allow the establishment of an electronic B2B-collaboration with multiple opposing parties.	High	Priority
17	Legacy system security is assured as they are not directly exposed to collaborating counterparts. Instead legacy systems remain securely on the internal level under the protection of several eSA levels.	Low	Difficulty
	eSA-compliant systems must not violate the security of other legacy systems that are vital for the day-to-day business of companies.	High	Priority
18	The collaborating parties first need to contact each other via the trusted-third party if they have not agreed a priori on an electronic B2B-collaboration for longterm. Hence, in eSA-compliant systems, prior contact is established before a collaboration is set up.	Low	Difficulty
	It is important that the collaborating parties can trust the origin of exchanged data.	High	Priority
19	Trust management is an ongoing research issue that is not under exploration for electronic B2B-collaborations. Hence, realizing comprehensive electronic trust management in eSA is not trivial.	High	Difficulty
	In an anonymized market that is driven by electronic services, it is not clear how much the counterpart can be trusted. Thus, mechanisms must be in place that allow to fill this knowledge gap about a potential collaborating counterpart.	High	Priority
20	eSA-compliant systems have a conceptual and external level to which subsets of the conceptual processes are projected.	Low	Difficulty
	When the engagement in an electronic B2B-collaboration results in the unintended disclosure of important business secrets, the existence of a company is in jeopardy.	High	Priority
21	This standard problem has been technically solved.	Low	Difficulty
	If the trusted-third party does not function, it is not possible for an eSA-compliant system to support anonymized markets with automated bidding and other services like inter-organizational verification components. Thus, only parties that already agree a-priori to collaborate, can engage in setting up an electronic B2B-collaboration that can not be verified in a satisfactory way.	High	Priority

Table 7. Justifying the ranking of scenarios (Part 3).

A.3 Scenario Specification

Since there is limited time available in an ATAM-evaluation, only the highest ranked scenarios are scrutinized and further refined. In the case of this evaluation, the highest ranked scenarios are depicted in Figure 18 to Figure 21. All scenarios fall into the category of use cases, i.e., they describe the user's intended interaction with the electronic B2B-collaboration system.

Scenario 5:
For a modeled eSourcing configuration, tools are available that detect control-flow errors in a way that enable respective parties to perform an internal modification of the process model without revealing business secrets to the counterparts.

Attribute(s) usability (error avoidance)

Environment eSA-compliant system

Stimulus created business-collaboration model

Response
A verification tool points out errors in the model only to the party concerned with correction measures while the opponent only receives a message that a mistake exists.

Architectural decisions	**Sensitivity**	**Trade off**	**Risk**	**Nonrisk**
Verification component in the trusted-third party.	S1			
GUI with separate views for collaborating parties			R1	
Recommendation component for fixing mistake			R5	
Dedicated server assigned to verification		T1		
Verification of collapsed net				N1

Reasoning
Inter-organizational verification ensures correct termination and must be checked before enactment.
The concerned collaborating party must be able to find the mistake and know how to correct it so that the overall configuration can terminate.
Still, business secrets must remain hidden from counterpart (see R1).

Architectural diagram
See the verification components in Figure 5 and Figure 7 of this paper.

Fig. 18. Specification of highly ranked Scenarios 5.

All the scenarios in Figure 18 to Figure 21 use the same template for their specification. A relevant part of the specifications are the architectural decisions in eSA for dealing with the scenarios. To the left, the decisions are listed and to the right whether they constitute so-called sensitivity or tradeoff points, risks or non-risks (see Section 2.2 for details). In Table 8, the sensitivity and tradeoff points, risks and non-risks are listed.

Scenario 7:
An error that occurs during the enactment of an eSourcing configuration is caught and managed without requiring stopping the enactment.

Attribute(s) usability (error handling)

Environment eSA-compliant system

Stimulus data-flow: wrong data sent

Response
Depending on the severity of the error, either exception handling follows till system recovery, or inter-organizational business-process compensation is started.

Architectural decisions	**Sensitivity**	**Tradeoff**	**Risk**	**Non risk**
Global versus local WFMS and Rules Engines.	S2			
A reliable coordination component.			R2	
Distributed WFMS and rules engines.				N2
Level architecture and global WFMS and rules engine replication.		T2		

Reasoning
Errors and compensations have several aspects, which can be grouped as business, conceptual, and technological. These different groups should be handled on different eSA levels to achieve a separation of concerns that reduces complexity.
For example, the WFMS and rules engine on the external level are concerned with business and conceptual exceptions and compensations, while the internal WFMS and rules engines deal with conceptual and technical exceptions and compensations.

Architectural diagram
See global and local WMFS and rules engines in Figure 5 and Figure 6 of this paper.

Fig. 19. Specification of highly ranked Scenario 7.

Scenario 8:
eSA provides the components required to verify the perspectives of data-flow, control-flow, resource management before enactment.

Attribute(s) usability (verification)

Environment eSA-compliant system

Stimulus Ready modeled eSourcing configuration

Response
Results of the verification, i.e., either errors are detected or there are no errors.

Architectural decisions	**Sensitivity**	**Tradeoff**	**Risk**	**Nonrisk**
Localize verification as far as possible.	S3			
Idem.		T3		
An evaluation component is part of eSA.			R3	
Verification components on conceptual level.				N3

Reasoning
It is important that an eSourcing configuration is thoroughly verified in all perspectives to ensure a correct enactment phase. When enactment fails, penalty payment must follow, customers are unsatisfied, etc., which is all undesirable.

Architectural diagram
Figure 5 and Figure 7 of this paper.

Fig. 20. Specification of highly ranked Scenarios 8.

Scenario 19:
An electronic business collaboration turns bad (i.e., because of fraud, delays, agreement violations) any it is not desirable any more to repeat the collaboration.

Attribute(s) security (trust management)

Environment eSA-compliant system

Stimulus A business party detects deviating business-collaboration behavior compared to what has been agreed.

Response Update of the reputation record about badly collaborating counterparts and possibly exception handling and compensation.

Architectural decisions	**Sensitivity**	**Trade off**	**Risk**	**Nonrisk**
Integrate additional trust components in trusted third party.	S4			
Integrate appropriate components.			R4	
		T4		
Refinement of trusted third party.				N4

Reasoning
In an anonymized electronic collaboration environment, it is necessary to integrate mechanisms for evaluating the reputation and trustworthiness of potential collaboration counterparts.

Architectural diagram
In Figure 5 of this paper, components for identity and reputation management are inserted in the eSourcing middleware and trusted third part components.

Fig. 21. Specification of highly ranked Scenarios 19.

Risk	Sensitivity	Tradeoff	Nonrisk	Explanation
	S1			GUI of verification tool that protects process details while allowing fault pinpointing.
R1				GUI that separates process views for respective collaborating parties for error detection.
		T1		Usability and performance during the setup phase are potentially diminished by bad GUI.
			N1	Support of correct-termination check for inter-organizational eSourcing configuration.
	S2			A coordination between global and local exception handling and compensation is essential.
R2				The global WFMS and rules engines are replicated and require coordination.
		T2		Due to replicated WFMS and rules engines, performance, usability, and modifiability are affected.
			N2	Locally occurring mistakes can be managed by global WFMS and rules engine.
	S3			Inter-organizational verification in many perspectives may be computationally too expensive.
		T3		Performance problems unless pragmatic heuristics are used. Usability issues because of GUI. Security is compromised if verification results are wrongly disclosed to collaborating counterpart.
R3				Even with verified perspectives, there is no guarantee they work together.
			N3	When certain rules are followed, control-flow verification can be successfully performed locally alone.
	S4			Trusted-third-party component lacks components for trust management.
		T4		Trust-management components may prolong the setup and post-enactment phase.
			N4	Trusted-third-party component can be refined with components to enable trust management.
R4				Trust, reputation, conflict components are missing in eSA.
R5				Without a recommendation component, fixing problems might be only possible for experts.

Table 8. Risks, sensitivity and tradeoff points, non-risks.