A Reference Architecture for Automation of Inter-Organizational Process-Oriented Collaboration

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Abstract

In today’s competitive, dynamic, and changing business environment, being able to collaborate globally within and beyond the enterprise borders is critical. Inter-Organizational Collaborations (IOCs) have been proposed as a response to the characteristics of highly competitive global business environments. So far, a number of reference models, frameworks, and ad hoc architectures related to some manifestations of inter-organizational collaborations have emerged. However, less research attention has been focused on concrete cases of IOCs establishment. This paper derives distributed service-oriented reference architecture for inter-organizational process-oriented collaboration support system from the conceptual architectures of several research projects in collaborative networks domain that covers both the IOCs’ establishment and management systematically. The proposed reference architecture can serve as a foundation for analysis and design of concrete architectures of IOC systems.

Keywords: Automation, Collaborative Networked Organization, Enterprise Integration, Inter-Organizational Collaboration, Reference Architecture

1. Introduction

Establishing Inter-Organizational Collaborations (IOCs) via association of various experienced and professional organizations is an effective and efficient solution for the survival of Small and Medium Enterprises (SMEs) in the current business environment. IOCs allow rapid formation of new business opportunities, producing the value-added market's need services, and more efficient competition upon other entities or groups. This is typically what forces SMEs to be a part of collaborative networks to be able to survive in the turbulent market [1].

In inter-organizational collaborations, “a variety of organizations that are largely autonomous, geographically distributed and heterogeneous in terms of their operating environment, culture, social capital and business goals collaborate to better achieve common or compatible goals, and these interactions are supported by computer networks” [2]. The fundamental idea underlying inter-organizational collaborations is the organizing and utilizing distributed capabilities that may be under the control of different ownership domains [3].
1.1 Research motivation and challenges

The main stages of IOCs life cycle namely creation, operation, evolution, and metamorphosis/dissolution, also, continuous management of structural/behavioral aspects of actors involved in collaboration are usually complex processes that consume many efforts, resources, cost, and time [4]. Utilizing automated tools for supporting these stages and aspects guarantees the required levels of efficiency. Based on this assumption, in recent years, extensive research efforts have been undertaken to automate the establishment of IOCs. The examined projects such as CrossWork [5], ECOLEAD (European Collaborative networked Organisations LEADership) [6], [7], SUDDEN (SMEs Undertaking Design of Dynamic Ecosystem Networks) [8], Pilarcos [9], MISE (Mediation Information System Engineering)[10], [11], eSRA (eSourcing Reference Architecture) [12], SOA4ALL [13], COIN [14], S-CUBE [15], CHOReOS [16], [17], etc. are some instances of these efforts. Our literature studies show that there is not any abstract model that includes a set of functionalities and services supporting both the automatic establishment and structural/behavioral management of IOCs.

1.2 Contributions

The main contribution of this paper is to present a distributed service-oriented reference architecture named RefIOC (Reference architecture for Inter-Organizational Collaboration) for an IOC support system that covers both the IOCs’ establishment and management systematically. In accordance with literature studies [1], [4], [5] as well as by taking into account the goals and visions of IOCs, the functional requirements that should be satisfied by the proposed reference architecture are as follow:

- q1. Formation requirements:
  - q11. Establishing a validated collaboration configuration in the form of a cohesive and trusted team with the desired competency;
  - q12. Supporting the contracting negotiations’ process;
- q2. Common collaboration space requirements:
  - q21. Providing semantic alignment among participants;
  - q22. Providing common working and sharing principles, rules, bylaws, policies and values;
  - q23. Providing a common set of base trustworthiness criteria;
- q3. Operation requirements:
  - q31. Right enacting of created collaboration configuration;
  - q32. Dealing with integration, interoperability, and collaboration problems;
  - q33. Monitoring the agreements and contracts;
  - q34. Assessing/Monitoring the competency, trust and performance of participants dynamically;
  - q35. Supporting/Handling the material/immaterial assets/values, marketing, financial, accounting and resources;
- q4. Post-operation requirements:
  - q41. Supporting the evolution process;
  - q42. Supporting the metamorphosis process;
  - q43. Supporting the dissolution process;
1.3 An overview of the proposed reference architecture

Figure 1 shows an overview of the RefIOC: the IOC formation subsystems (①) take partners’ local business processes (②), and compose them into a global business process. The constructed process is then enacted by the Global business process enactment subsystems (③). During the enactment of the global business process and depending on the control flow, the Local business process enactment subsystems are invoked to execute the local partner business processes (④) that link the partner Web services (or interfaced legacy systems) (⑤). The Post-operation subsystems provide mechanisms that enable the IOC to evolve during enactment time, metamorphose or dissolve depending on the particular set of circumstances (⑥). The structural/behavioral management of IOC through its entire life cycle is delegated to IOC management subsystems (⑦). Clearly, the system supporting an IOC must be highly distributed, because the IOC itself consists of many distributed, autonomous parties with local systems that must be integrated into the global process. Accordingly, the subsystems of the conceptual and internal levels of the system are distributed across autonomous parties. Since the reference architecture is based on a Service-Oriented Architecture (SOA) paradigm, it and all available partners’ Web services can be deployed on an Enterprise Service Bus (ESB) (in case of necessity, specific interfaces are used to connect the legacy systems). ESB is a middleware that provides standardized communication services (such as routing, filtering, QoS, encryption, archiving, message queuing, logging, communication trace and others) in a multi-peer client server architecture [18]. The collaborative behavior is consequently managed by the ESB among partners’ services.

Figure 1. An overview of the IOC support system reference architecture
1.4 Organization of the paper

The remainder of the paper is organized as follows. In Sections 2, the related works are presented. The deriving process of ReIoC is elaborated in Section 3. Section 4 states threat to validity and Section 5 evaluates the proposed reference architecture through (1) mapping of several examined projects at its domain onto it, (2) based on an experience-based assessment. Finally, we concluded the paper in Section 6.

2. Related Works

The concept of Virtual Enterprise/Virtual Organization (VE/VO) is the most discussed type of IOCs. However, the idea of the VE/VO was not ‘invented’ by a single researcher; rather it is a concept that has matured through a long evolution process [19]. A brief historical perspective of the VO’s is presented in [19]. Levels of integration and main phases in manufacturing enterprises’ integration, some integration technologies and support paradigms, and examples of VO-related projects are the principal issues in this paper. In order to define a reference model for collaborative networks (ARCON), a preliminary analysis was introduced in [20] and then a comprehensive modeling framework was proposed as a first step towards the elaboration of a reference model for collaborative networks in [21]. The concepts developed within the ECOLEAD project, e.g. Virtual Organization Breeding Environment (VBE), VO creation schema, VO composition, partners’ search and selection, and definition of roles in VBE are the fundamental elements in the development of Virtual Organization Breeding Methodology (VOBM). VOBM defines the structure of VBE and VO architectures in a service-oriented environment, as well as an architecture development method for virtual organizations (ADM4VO) [22]. In [23], an instantiation methodology is presented to address a number of steps for establishing and characterizing the management functionalities of a VBE systematically. In order to increase the flexibility and re-configurability of the VE system, an Ontology-based Multi-Agent Virtual Enterprise (OMAVE) system is proposed in [24] in the standard ontology languages RDF, RDFS and OWL using the Protégé ontology editor. This system helps SMEs to shift from the classical manufacturing to high-value-added, high-tech, and innovative producing. In [25], the authors focus on an ontology-based process model for the business architecture of a virtual enterprise that provides a common semantic and communication protocol between participants in a VE. The suggested process model is based on perspectives of the OMG’s Model Driven Architecture (MDA) to secure consistency between business partners and has a single integrated meta-model that describes the internal and intra business process of a VE.

A Federated Collaborative Networked Organization Model (FCNOM) which describes some perspectives within the Collaborative Networked Organization (CNO) life cycle (e.g., organizational behavior perspectives, CNO federation modeling perspectives, and external perspectives) is proposed in [26]. This model provides a clear and unified view of the CNO environment, supports the automation of Dynamic Virtual Organization (DVO) configuration, minimizes the negotiations between CNO partners, facilitates the decision making, and achieves harmonization among CNO partners. In [27], the CommonKADS knowledge engineering methodology is used to model the life cycle, identification, and formation of DVOs. In [28], the factors contributing to the
effective inter-organizational collaboration are introduced and the impact of these factors on actions undertaken in public management to systematize them are described.

The service-oriented architecture has been proposed in [29] as an approach to implement VOBE. In this paper, a set of core services include competence management service, social network service, VO collaboration service, VO creation service, and VO monitoring service are provided to support SOVOBE members and virtual organizations throughout their lifecycle.

With the emerging of Cloud computing concept, Cloud-based collaborations have been booming in recent years. The required functionality for a collaborative networks environment and a Cloud-based platform (called GloNet platform) supporting the creation of software solutions for the collaborative design and operation of complex service-enhanced products have been described in [30]. The GloNet platform has been built according to a tailored Cloud-based principle, considering specific requirements of collaborative networks, and has three layers: service-enhanced product support, collaborative networks management system, and Cloud-based platform. The Cloud-based platform is also composed of three layers: presentation layer, business logic layer, and data layer. This platform provides mechanisms for the integration of external systems and services that complement the basic features of it.

The concept of Cloud Manufacturing (CMfg), including its background, architecture, typical characteristics, key technologies for implementing a CMfg, and the construction of manufacturing Cloud is discussed in [31]. CMfg uses the network, Cloud computing, service computing and manufacturing enabling technologies to transform manufacturing resources/capabilities into manufacturing services, which can be managed and operated in an intelligent and unified way to enable the full sharing and circulating of manufacturing resources/capabilities. Wenhao in [32] discusses two issues: the workflow system framework for the Community Cloud and the scheduling strategy for such workflow system. For the first issue, he proposes a novel workflow system framework which supports the fast collaboration of the Community Cloud via a process-driven method. For ensuring the fast collaboration mechanism work in high efficiency by the framework, Wenhao offers a Community Cloud-oriented task scheduling strategy called the Unified Scheduling Strategy for Instance-intensive Workflows (USS-I) in the second issue.

Industry 4.0 is mainly characterized by an increasing digitalization and interconnection of manufacturing systems, products, value chains, and business models. It is often described in terms of its six main characteristics, namely: vertical integration/networking, horizontal integration/networking, through-engineering, acceleration of manufacturing, digitalization of products and services, and new business models and customer access or involvement. The central features of industry 4.0 are the Cyber-Physical Systems, Internet of Things, and Internet of Services. In [33], the authors believe that for properly understanding the vision of Industry 4.0, one needs to look at it from the lens of collaborative networks. In this paper, for solving the issues emerge from each characteristic of Industry 4.0, a number of contributions from the perspective of collaborative networks are categorized.

The authors in [34] strive to answer to these two basic questions: (1) What does the information system of a collaborative network look like? (2) What is the definition of agility of such information systems? In response to the first question, the information systems dedicated to supporting collaborative organizations should be able to perform interoperability for data messages, services, and workflows with respect to information,
functions, and processes layers. For exploring the question of agility of information systems to support collaborative organizations in accordance with the four main elements of agility (detection, adaptation, reactivity, and efficiency), the authors refer to four articles in this context.

Cloud Manufacturing is a next-generation manufacturing environment composed of ‘Internet-of-Things’ (IoT) and ‘Internet-of-Services’ (IoS), parallel to each other. [35] contributes to the design of Cloud Manufacturing systems by defining a framework for dynamic integration of self-contained and autonomous ‘components’ (a.k.a., Internet of things) and ‘services’ (a.k.a., Internet of services) in a collaborative network of organizations. The developed framework is formulated as a bi-objective mixed-integer program and solved via an efficient socio-inspired tabu search. The framework can be applied for improving the utilization, service level, and thus agility of CNOs, through dynamic matching and sharing of components and services.

As mentioned in Section 1.1, there are various examined research projects in the context of collaborative networks. In Sections 3.1, 3.2, 3.3, and 5.1.2, when using some of these projects in the derivation and evaluation processes; a brief description about each of them will be presented.

3. Deriving the RefIOC

The reference architecture for a domain facilitates the design of all concrete architectures at the domain. It defines the fundamental components of the domain as well as the relationships between these components [36]. The identification of reference architecture type at the start of the design process has a profound impact on the next steps of the process. A multi-dimensional classification for congruent reference architectures has been proposed in [37] according to their context, goals, and design. Based on this classification, our reference architecture is a reference architecture of type 3 (classical, facilitation architecture designed for multiple organizations by an independent organization), because the practical experiences required for application in the proposed reference architecture exist at the time of its design and have been tested in practice. The design and evaluation of the reference architecture can consequently be performed according to the projects carried out at the collaborative networks domain.

We used the available documents of CrossWork [5], ECOLEAD [6], [7], eSRA [12], SOA4ALL [13], COIN [14], S-CUBE [15], CHOREOS [16], [17] projects in our deriving process, but, due to space constraints, the discussion in this section focuses on deriving the reference architecture from the practical experiences of CrossWork, ECOLEAD, and eSRA projects as well as the literature studies and empirical research on IOC context.

The reason for addressing these three projects in deriving process was their different focus on the topic of collaborative networks. The focus of CrossWork and eSRA were to create the software necessary for automatic establishment of virtual enterprises [5], [12], whilst the ECOLEAD project focused on developing a management system that could manage a wide variety of entities and concepts co-exist in a typical VBE environment [6]. These three projects are exactly consistent with our first contribution (offer a reference architecture covering both the IOCs’ establishment and management systematically). In addition, the subsystems derived from the other projects had overlap with the subsystems derived from these three projects, so, due to space constraints, we will not discuss them in detail.
For each of these three projects, we use their conceptual architecture diagrams, provide a brief background about the projects, and show the deriving of our reference architecture from their conceptual architectures. In the deriving diagrams, a square box is a subsystem in the conceptual architecture and a rounded-dotted box is a corresponding subsystem in our reference architecture.

To make the proposed method clearer, Figure 2 summarizes the steps of our research method.

**3.1 CrossWork project**

CrossWork project was created to develop software and business mechanisms, which can bring the vision of Instant Virtual Enterprises (IVEs) closer to reality by automating the formation, operation, and evolution of an IVE[5]. Figure 3 shows the CrossWork conceptual architecture (adapted from [5]) as well as the derived subsystems from it for the RefIOC. The CrossWork architecture has been mapped to the three-level framework for inter-organizational process-oriented collaboration. This framework distinguishes between external, conceptual, and internal levels [37]. The tasks of CrossWork modules are described in Appendix A.

In RefIOC, the tasks of the Legacy integration module are delegated to the ESB, which is not part of the proposed architecture.

**3.2 ECOLEAD project**

The ECOLEAD was a large EC-funded project that had focus on providing new and strong foundations, mechanisms, and methodologies for forming, governing, and managing of collaborative and distributed industry society. The underlying idea of ECOLEAD was that efficient launching and operation of virtual organizations require preparedness, both in the VO environment and in (potential) partners[7].

Figure 4 shows the ECOLEAD conceptual architecture (adapted from [6]) as well as the derived subsystems from it for the RefIOC. For improving the preparedness of its member organizations towards collaboration in potential VOs, the VBE uses a VBE Management System (VMS) to support the management and processing of information/knowledge needed to effectively create, operate, and evolve VBEs. The tasks of ECOLEAD subsystems are described in Appendix B.
Since in our reference architecture, the tasks of VBE are delegated to a trusted third-party (see Section 3.5), there is no need to VO information management subsystem. In addition, CO-Finder subsystem generates and proposes a new collaboration opportunity that will trigger the formation of a new VO. This subsystem also does not exist in RefIOC, because the collaboration opportunity owner provides the new collaboration opportunity.
3.3 eSRA project

eSourcing Reference Architecture (eSRA) presents a reference architecture for development and assessment of enterprise-collaborations. It offers a dynamic method for establishment of inter-organizational collaborations, in other words, the architecture enables the organizations involved in a collaboration to dynamically integrate their business processes with the processes of new organizations interested in taking part in the inter-organizational collaborations. In eSRA reference architecture, all parties contain the same set of components that distributed across external, conceptual, and internal layers [12]. Figure 5 shows the eSRA reference architecture as well as the derived subsystems from it for the RefIOC. Table 4 in Appendix C provides a brief description of the eSRA components.
In RefIOC, the tasks of Coordination_interface and Web_Service_Wrapping_Legacy_System components are delegated to the ESB, which is not part of the proposed architecture. Also, the eSRA Pattern_Knowledge_Base, Rules_Repository_Manager, Process_Snippet_Manager, and Production_Data_Manager components, which correspond to data repositories, have been ignored in RefIOC, because the RefIOC focuses only on processing subsystems and their relationships. Eventually, in our solution, the eSRA Trusted_Third_Party tasks are carried out by the TTP which is an entity independent of RefIOC.

### 3.4 Proposed reference architecture

Table 1 summarizes the reference architecture subsystems and their corresponding modules (if any) from CrossWork, ECOLEAD, eSRA conceptual architectures. The resulting reference architecture is shown in Figure 6. The black boxes in Figure 6 show the new subsystems that have been added to the reference architecture based on the other literature studies and empirical research on IOC context and did not exist in the examined conceptual architectures.
<table>
<thead>
<tr>
<th>RefIOC subsystems</th>
<th>CrossWork</th>
<th>ECOLEAD</th>
<th>eSRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaboration opportunity management</td>
<td>Goal decomposition</td>
<td>CO characterization &amp; rough planning</td>
<td>N/A</td>
</tr>
<tr>
<td>Team formation</td>
<td>Team formation</td>
<td>Partner search &amp; suggestion</td>
<td>N/A</td>
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<tr>
<td>Business process integration</td>
<td>Workflow composition</td>
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<td>Workflow_Composer</td>
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<tr>
<td>Business process verification</td>
<td>WF verification, WF prototyping</td>
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<td>Verifier; Simulator</td>
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<tr>
<td>Transaction verification</td>
<td>Transaction verification</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Business process state checker</td>
<td>WF state checker</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Global enactment engine</td>
<td>Global enactment</td>
<td>N/A</td>
<td>Global_WFMS</td>
</tr>
<tr>
<td>Global transaction management</td>
<td>Global transaction management</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
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<td>Translator</td>
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<td>N/A</td>
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<tr>
<td>Global business rules engine</td>
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<td>N/A</td>
<td>Global_Rules_Engine</td>
</tr>
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<td>Process design</td>
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<td>Process_Modeler</td>
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<td>Local enactment</td>
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<td>Local_WFMS; Process_Data_Manager</td>
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<tr>
<td>Local business rules engine</td>
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<td>N/A</td>
<td>Local_Rules_Engine; Rule_Data_Manager</td>
</tr>
<tr>
<td>Local transaction management</td>
<td>Local transaction management</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Local enactment monitor</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Partners information management</td>
<td>N/A</td>
<td>Profile &amp; competency management; Membership &amp; structure management</td>
<td>N/A</td>
</tr>
<tr>
<td>Decision support</td>
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<td>Decision support</td>
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</tr>
<tr>
<td>Trust management</td>
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<td>Identity_Management; Reputation_Management</td>
</tr>
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<td>N/A</td>
<td>Ontology discovery &amp; management</td>
<td>N/A</td>
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<tr>
<td>E-contract management</td>
<td>Contract establishment, Contract monitoring</td>
<td>Contract negotiation wizard</td>
<td>Contracting_Client</td>
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<td>Other management subsystems</td>
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<td>Bag of assets management; Support institutions management</td>
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<td>Governance management</td>
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<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Performance management</td>
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</tr>
<tr>
<td>Evolution</td>
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<tr>
<td>Metamorphosis</td>
<td>N/A</td>
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<td>N/A</td>
</tr>
<tr>
<td>Dissolution</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Figure 6. Reference architecture for automation of inter-organizational process-oriented collaboration

3.5 Comparison of RefIOC with CrossWork, ECOLEAD, and eSRA architectures

Creation phase - Maintaining a community of members is an essential topic for collaborations in an anonymous collaboration environment. This ongoing activity is an issue transcending the life cycle of a single IOC. In CrossWork project, for the Creation stage, a community of potential VE partners is maintained in a knowledge base. This knowledge base contains specific knowledge about organizations within a market, their capabilities and their local processes. The potential members for an IVE are then selected from this knowledge base by the Team formation module. In eSRA, a component of reference architecture termed Trusted_Third_Party between collaborating counterparts offers searchable information about collaborating parties using a publish/subscribe style. In ECOLEAD, for VO creation, the partners are primarily selected from the VBE members that have been previously recruited. For short-term collaborations, the VBEs bring certain challenges. For organizations that are interested in taking part in inter-organizational collaborations, there are some barriers to participate in VBEs [38]: (1) return on time/cost investment (fear of not having Return On Investment (ROI)), (2) losing decision making power, (3) trust and intellectual property rights problems, (4) the high level of required commitment, and (5) negative
impact on the competitiveness. Furthermore, to respond to a new collaboration opportunity in a VBE, the collaborations are usually limited within the VBE span.

In comparison with these three projects, in our approach, the team members are requested from a platform called Trusted-Third Party (TTP), owned and managed by a third-party supplier outside of the reference architecture. TTP eliminates the challenges mentioned above. Although the details of TTP architecture are out of this paper’s scope (and we omit it from our architectural design), we assume that the followings are the least responsibilities of it:

- Registering the new applicants interested in taking part in the inter-organizational collaborations after the assessment of their base trust level.
- Allowing to the registered applicants to submit their profiles and competencies.
- Providing a bidding environment for searching and selecting the best applicants.
- Supporting the contracting negotiations for setting up a collaboration configuration with known collaborating parties.
- Making the skills/resources offers and requests accessible and searchable for potential business partners.

Operation phase- In eSRA, each party contains the external layer (also other layers) and its components, but for affecting the performance positively, the external layer subsystems of the RefIOC can be deployed on a centralized platform (This is valid for CrossWork architecture as well): one business process engine (Global enactment engine) executes the global business process and synchronizes a number of other business process engines (Local enactment engines) that execute the local business processes.

In RefIOC, it has been attempted to use the ECOLEAD management components alongside the subsystems considered for IOC Creation, Operation, Evolution, and Metamorphosis/Dissolution phases (derived from CrossWork and eSRA).

3.6 RefIOC subsystems

In this section, the subsystems of each RefIOC layer and the services provided by them are discussed, separately. The reader must notice that the subsystems of the proposed distributed reference architecture have introduced by assuming that there is an ESB platform with foundation capabilities. On a technical point of view, the ESB could implement some of these subsystems if there was an extended version of it (e.g. some ESBs have process choreography and service orchestration capabilities as their core functionalities). That's why the ESB is separate from the reference architecture in the proposed solution.

3.6.1 External level

The external level stretches across the domains of IOC collaborating parties. IOC formation, Global business process enactment, Post-operation, and IOC management packages include a subset of reference architecture subsystems, which located on the external level.

3.6.1.1 IOC formation subsystems

Collaboration opportunity management (COM). As the Creation phase of IOCs is triggered in response to a collaboration opportunity, we introduce the COM subsystem in our reference architecture to manage the collaboration opportunities. The services provided by this subsystem enable the IOC planner to (1) customize the core
collaboration opportunity model to the COM (e.g. as the IOC core collaboration opportunity sub-ontology), (2) submit the details of the collaboration opportunity to the COM, and (3) decompose the collaboration opportunity into a set of skills/resources required to respond to collaboration opportunity, according to the information and structures available in the IOC ontology.

Team formation. Team formation subsystem attempts to select potential members for an IOC. It submits each received skill/resource from COM subsystem along with their requirements/competencies to TTP. The TTP performs the bidding process among its registered applicants to select a set of qualified candidate providers whom provide the requested service and returns the result to the Team formation subsystem. In the next step, the Team formation subsystem selects the best fit partner for collaboration configuration. The process is repeated until all skills/resources are assigned to the proper collaborators and the team members are identified.

Business process integration. The subsystem requests the projected business processes from the team members and supports for the (semi-) automatic composition of a global business process from these business processes. The constructed global business process must satisfy the control- and data-flow dependencies between local business processes of the team members as well as coordinate their work. Some team members may need to be replaced at this point to achieve the best fitness. After verifying the global business process, the IOC administrator attempts to establish a contractual consensus (expressed as rules concerning the future collaboration) among the collaborating parties using the E-Contract management subsystem. Finally, if necessary, the subsystem invokes the Ontology management subsystem to integrate the team members’ ontologies into the IOC ontology.

Business process verification. The subsystem ensures that the composed global business process contains no errors before it is actually performed. It analyses all potential behaviors of the constructed global business process model and verifies the functionality of it in a simulated environment.

Transaction verification. This subsystem verifies the transactional behavior of composed global process. It is used after the verification of global process by the Global business process verification subsystem [5].

Business process state checker. The subsystem checks the consistency of the new global process after the change. It checks the consistency of the new global process with process state that was reached with old process definition [5].

3.6.1.2 Global business process enactment subsystems

Business process translator. The subsystem transforms the global business process specifications to languages, which can be processed by the machine.

Global enactment engine. The subsystem is a run-time environment that executes instances of translated global business process to orchestrate the execution of all local business processes residing in each of the IOC member organizations [5]. As the local partners expose their business processes as Web services (see Section 3.6.2), the connection between the Global enactment engine subsystem and the Local enactment engine subsystems of IOC members is supported through the WSDL interfaces exposed by the local partners. The Global enactment engine also supports the IOC administrator to instantiate (and update, if necessary) all global variables required during the execution of the global business process. In addition, it enables the administrator to analyze and pass any control orders to the local business processes.
Global business rules engine. The subsystem enables the IOC administrator/planner to submit/manage the contractual or other global business rules to this subsystem. In fact, this subsystem allows non-programmers to add or change business logic in the Global enactment engine.

Global enactment monitor. The subsystem gathers, stores, and analyses all (global and local) monitoring details during execution of the global business process and informs the status of its execution to the IOC administrator (the local status of execution is achieved from the Local enactment monitor subsystem).

Global transaction management. This subsystem is used to safeguard the reliability of the global business process. To achieve this aim, the Global transaction management subsystem requires the relaxed ACID (Atomicity, Consistency, Isolation, Durability) transaction properties. The steps of the global business process do not behave strictly atomically, as this would imply the undoing of large amounts of work in case of an error, also, they are not executed in strict isolation, as strict isolation would prevent the sharing of information as required in a business process management environment. A rollback mechanism at this level is required though, to be able to undo a business process to a certain point in case of errors. Rollback should offer application-oriented semantics, i.e. it should return a business process to a state that is identical to a previous state from a business point of view, not necessarily from a database point of view [39].

3.6.1.3 Post-operation subsystems

During the IOC operation phase, three actions might occur due to market changes and new trends’ appearances: evolution, metamorphosis, and dissolution. Sometimes, it might be necessary to make some changes to the global business process while it is being executed. This, triggers the Evolution subsystem. The IOC Metamorphosis refers to the IOC nature adaptation by changing its strategy, business processes and structure to tactically respond to new market changes and trends, permitting IOC to remain competitive at its domain sector. A short-term IOC will typically dissolve after accomplishing its goals (Romero et al., 2008). The Global enactment monitor subsystem triggers one of the following subsystems depending on the nature of the circumstances analysis.

Evolution. The subsystem provides the systematic mechanisms for performing the what-if analysis for changes that occur during the global business process enactment. If changes are approved, the Evolution subsystem supports the IOC administrator to change the global business process while it is being executed by Global enactment engine subsystem (e.g. reassign tasks, change partners, etc.). Also, it allows the IOC administrator to design, operate, and control the new management approaches. Note that when the new global process is created, it is checked by Business process state checker subsystem.

Metamorphosis. The subsystem supports the IOC administrator/planner for re-strategic planning/implementation of IOC and re-launch it [23].

Dissolution. The subsystem aims at returning the IOC assets to their owners, ending affairs and contracts with all IOC actors (including customers) and shutting down ICT-infrastructure. Furthermore, it can captures and transfers the collected knowledge during the entire IOC life cycle to other IOCs [23].
3.6.1.4 IOC management subsystems

The IOC management subsystems support the IOC through its entire life cycle (from the Creation stage to the Dissolution stage). Details of the relations among the subsystems of this collection with the subsystems of other levels’ packages have been omitted to simplify the Figure 5.

Partners information management (PIM). The subsystem periodically receives the latest version of IOC partners' profiles, competencies, and trust data from the TTP. In order to facilitate the dynamism of IOC, the periodic receipting and processing of partners' information are necessary. In addition, this subsystem supports the IOC administrator to manage the roles, rights, and responsibilities of the IOC partners.

Trust management. In Creation stage of an IOC, the candidate partners with a base level of trust are introduced by TTP, but it is insufficient. Establishing trust relationships among partners for facilitating their co-working is an important factor in inter-organizational collaborations. The Trust management subsystem is responsible for this important function. Other services provided by this subsystem include [6]: measuring the trustworthiness of a partner in order to use for a specific trust objective, tracking the trust level evolution of partners by trustors, changing of weights incorporating in the equations applied for the development of mechanisms for assessing trust level of partners, updating the trust related data by the partners, and managing all the trust related data in the system by the administrator.

Decision support. This subsystem supports the monitoring of certain indicators in the IOC and provides on-time notifications and warnings. Warning for lack of partners’ performance, warning for emerging IOC competency gap (during the evolution stage), warning for low partners’ trustworthiness, warning for metamorphosis time, and warning for dissolution time are the proactive notifications that are generated by Decision support subsystem [6]. In addition, it evaluates the impact of acquiring new or losing existing partners of IOC. Aligning the strategies of IOC members is another service provided by this subsystem [40].


E-contract management. At Creation stage of an IOC, this subsystem supports the establishment of contractual consensus among the collaborating parties, and subsequent ongoing monitoring the established agreements and contracts.

Ontology management. The IOC ontology provides a unified and formal conceptual representation of the heterogeneous knowledge within the IOC environments. The Ontology management subsystem aims to provide a common understanding of the IOC-related concepts for all IOC actors, as well as it facilitates the reusability/interoperability of knowledge accumulated in one IOC with other IOCs [41]. Other services provided by this subsystem include [6]: supporting the IOC ontology developers to semi-automatically discover the ontology elements from different sources, allowing the authorized IOC partners to manage the IOC ontology, allowing all IOC partners to familiarize themselves with the IOC terminologies, supporting data processing for different IOC functions by using the ontology’s knowledge classifications, and supporting the integration of IOC members’ ontology into the IOC.
ontology. Note that all subsystems in the reference architecture should be aware of IOC ontology.

*Governance management.* The subsystem allows the authorized IOC actors to manage the IOC governance principles, rules, and bylaws via a user-friendly interface.

*Other management subsystems.* For complete management of IOCs entire life cycle, it may be necessary to have a set of management subsystems other than those mentioned above e.g. Bag of assets management, Value system information management, Risk management, ICT management, Financial, accounting and resource management, Strategic and marketing management, etc.

### 3.6.2 Conceptual level

The design of local business processes within a specific IOC partner takes place at the conceptual level. In proposed reference architecture, we consider a business process as a large-grained Web service which its steps execute activities that are centered on invoking partner services to perform tasks and return results to the process [5]. Therefore, a business process WSDL file can introduce the control and data flow interface of the process. This file is next used by the Global enactment engine subsystem to interact with the Local enactment engine subsystem to execute the local business process. The conceptual level comprises a subsystem:

*Business process modeler.* The subsystem provides three application services: (1) it provides a visual modeling environment for the IOC partners to model and verify their local business processes, (2) it enables the partners to specify a projection (selected internals of the conceptual level specification) of their business process’ specification to the outside world, and (3) it translates the business process model to languages, which can be processed by the machine. An executable specification of the designed business process is next mapped on to the internal level for use within the Local enactment engine subsystem and a projection of it is used by the Business process integration subsystem.

### 3.6.3 Internal level

The internal level provides capabilities for executing of local business process definitions owned by IOC partners. This level comprises the following subsystems:

*Local enactment engine.* The subsystem is a run-time environment that is capable of executing instances of local business process definition owned by the partners of an IOC. It interfaces to the Global enactment engine subsystem through the WSDL interfaces defined for the local business processes. It also provides the Local variables customizing service supporting the local suppliers to instantiate (and update, if necessary) all local variables required during the execution of the local business process.

*Local business rules engine.* The subsystem allows the local partners to add or change business logic in the Local enactment engine through creating, updating, and deleting the required business rules in the Local business rules engine subsystem.

*Local enactment monitor.* The subsystem gathers, stores, and analyses all local monitoring details during execution of the local business process and informs the execution status to the local partners and Global enactment monitor subsystem.

*Local transaction management.* This subsystem is used to safeguard the reliability of the local business process. To achieve this aim, the Local transaction management subsystem requires the strict ACID transaction properties. In this level, a business
process is presented with critical and non-critical steps. The critical steps should ideally be executed in strict atomicity and isolation. A rollback mechanism should offer complete undo to the pre-step state in case of critical errors. Non-critical steps allow the definition of process parts that cannot cause critical errors and hence do not require rollback functionality. Local transaction management subsystem also provides a concurrency control mechanism to regulate the data access between concurrent steps of the local business process [39].

4. Threats to Validity

In this section, we discuss three types of threats that affect the validity of our study as suggested by Jedlitschka et al. [42]:

Threats to construct validity: checks whether we have used the adequate instruments in our study to derive the constructs [42]. As described in Section 3, this paper focuses on deriving and evaluating the reference architecture from the available practical experiences of several projects: CrossWork, ECOLEAD, SUDDEN, eSRA, Pilarcos, MISE, SOA4ALL, COIN, S-CUBE, and CHOREOS. One of the limitations of this strategy was the lack of direct access to the conceptual architectures for some of these projects. So, for use in the reference architecture, we, ourselves, had to interpret and extract the modules involved in collaboration from their available documents.

Threats to internal validity: focuses on factors that might have causal effects on the design and enactment of the study [42]. One potential threat to internal validity of our research is the selection of the most successful projects for use in the deriving/mapping process. To minimize this risk, we attempted to use the examined research projects that were founded by authoritative founders.

Threats to external validity: External validity is concerned with to what extent it is possible to generalize the findings [42]. Although, the proposed reference architecture is valid for most of the collaborative networks manifestations, it uses an explicitly process-oriented approach in establishment of IOCs, so it is generally applicable for supporting the process-oriented collaborations (vs. other forms e.g. agent-based collaborations). The applicants interested in participating in inter-organizational collaborations need to offer the publicly visible specifications of their business processes.

5. Evaluating the RefIOC

The existing methods for evaluation of concrete architectures cannot be directly used for evaluation of reference architectures because these methods cannot cover the general nature of reference architectures. In Section 5.1, we first evaluate the functional completeness of the reference architecture through the mapping between its functional requirements and the proposed subsystems of the reference architecture. Since the proposed architecture is a reference architecture of type 3 (see Section 3), as the deriving process, the completeness evaluation of it can also be performed through mapping of several examined projects at its domain onto the reference architecture.

In [43], the author identifies the following methods for assessment of software architectures with respect to quality attributes: scenario-based evaluation, simulation, architectural prototype, mathematical modelling, and experience-based assessment. In latter method, the quality attributes are assessed based on the experience of architects.
Accordingly, in Section 5.2, we evaluate the proposed reference architecture based on the architectural decisions made to see which extent the reference architecture meets the set of non-functional requirements.

5.1 Functional completeness check

5.1.1 Mapping between the functional requirements and the subsystems

Table 2 shows the mapping between the functional requirements (listed in Section 1.2) and the subsystems of the RefIOC. As it can be seen, the RefIOC provides support for each functional requirement in its design.

<table>
<thead>
<tr>
<th>Functional requirement</th>
<th>RefIOC subsystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>q11</td>
<td>Collaboration opportunity management, Business process integration, Business process verification, Transaction verification, Team formation, Partners information management, Trust management</td>
</tr>
<tr>
<td>q12</td>
<td>E-Contract management</td>
</tr>
<tr>
<td>q21</td>
<td>Ontology management</td>
</tr>
<tr>
<td>q22</td>
<td>Governance management, Global business rules engine</td>
</tr>
<tr>
<td>q23</td>
<td>Trust management</td>
</tr>
<tr>
<td>q31</td>
<td>Business process translator, Global enactment engine, Global transaction management, Global business rules engine, Global enactment monitor, Local enactment engine, Local business rules engine, Local transaction management, Local enactment monitor</td>
</tr>
<tr>
<td>q32</td>
<td>ESB</td>
</tr>
<tr>
<td>q33</td>
<td>E-Contract management</td>
</tr>
<tr>
<td>q34</td>
<td>Trust management, Performance management, Decision support</td>
</tr>
<tr>
<td>q35</td>
<td>Other management subsystems</td>
</tr>
<tr>
<td>q41</td>
<td>Evolution, Business process state checker</td>
</tr>
<tr>
<td>q42</td>
<td>Metamorphosis</td>
</tr>
<tr>
<td>q43</td>
<td>Dissolution</td>
</tr>
</tbody>
</table>

5.1.2 Mapping of examined projects onto the reference architecture

A reference architecture has been defined as an abstraction of concrete architectures from a certain domain [36]. Therefore, it must be comprehensive enough to cover the concrete architectures of that domain. In following, we verify the completeness of our reference architecture through the mapping of it onto two examined projects: SUDDEN [8], [44] and MISE (Mediation Information System Engineering) [10], [11].

**SUDDEN project.** The primary focus of SUDDEN project was to enable SMEs to collaboratively create, optimize, and coordinate supply networks. The SUDDEN approach tries to bring together advances in “collaborative planning”, “delayed partner recruitment”, and “systematic evolution of supply networks” [8], [44]. Figure 7 shows the conceptual architecture of SUDDEN project. Table 5 in Appendix D provides a brief description of the SUDDEN subsystems. The mapping of SUDDEN conceptual architecture onto the RefIOC is also illustrated in Figure 7. As Figure 7 shows, the SUDDEN project fits well in the RefIOC.

The Network exploration and the Legacy systems integration subsystems in SUDDEN architecture are covered by the TTP and ESB respectively, which are not part of the RefIOC.
**Figure 7. Mapping of SUDDEN conceptual architecture onto the RefIOC**

**MISE project.** The MISE project is a Model-Driven Engineering/Business Process Modelling (MDE/BPM) approach which deploys a service-oriented Mediation Information System (MIS) ensuring the interoperability and collaboration among the IS of potential partners. Two iterations of the MISE project have already been performed. MISE 1.0 [45], [46] ran from 2004 to 2010. MISE 2.0 [47], [48] started in 2009 and ends in 2013. The third iteration, MISE 3.0 [10], started in 2011 and is currently ongoing. Table 3 summarizes the mapping of MISE specifications onto the RefIOC. As Table 3 shows, the MISE project also fits well in the proposed reference architecture. Of course, since the RefIOC attempts to cover both the IOCs’ establishment and management activities systematically, has additional subsystems that do not exist in MISE project.
5.2 Quality attributes evaluation

Table 3. Summary of the MISE project to RefIOC mapping

<table>
<thead>
<tr>
<th>Project level</th>
<th>MISE step/framework</th>
<th>Description [10]</th>
<th>Output</th>
<th>RefIOC subsystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business level</td>
<td>1. Design of collaboration model</td>
<td>The step concerns the gathering of knowledge (collaborative network, partners, common goal, and shared functions of partners) about the considered collaborative situation.</td>
<td>Collaboration opportunity</td>
<td>Collaboration opportunity management, Team formation</td>
</tr>
<tr>
<td></td>
<td>2. Deduction of the appropriate business/technical collaborative behavior model</td>
<td>The step deals with the automated deduction of not only the appropriate business behavior, but also the appropriate technical behavior collaborative processes, based on the knowledge collected at the previous step. Schematically, the aim is to select and organize partners’ services according to the objectives and environment of the collaboration.</td>
<td>Collaborative process cartography</td>
<td>Business process integration, Business process verification, Transaction verification</td>
</tr>
<tr>
<td></td>
<td>3. Design of collaborative workflow</td>
<td>The previously deduced business behavior (processes) is translated into a technical behavior (workflows) to be implemented. The goal is mainly to match services with activities and data with information.</td>
<td>Executable workflow</td>
<td>Business process translator</td>
</tr>
<tr>
<td></td>
<td>4. Deployment and orchestration of the MIS</td>
<td>The previously obtained workflows are integrated in a workflow engine to be executed on an ESB. All available Web services of the partners are connected on the same ESB (in case of necessity, specific interfaces are also deployed to connect other service or even human tasks). The collaborative behavior is consequently performed on this middleware among partners’ services.</td>
<td>MIS</td>
<td>Global enactment engine</td>
</tr>
<tr>
<td>Agility level (Framework)</td>
<td>Detection of evolution and adaptation of behavior</td>
<td>The agility of the MIS is based on event analysis (according to the received event) and on behavior adaptation (by re-invoking step 1, step 2, step 3 or step 4, depending on the nature of the event analysis)</td>
<td>Updated models</td>
<td>Global enactment monitor, Evolution, Business process state checker</td>
</tr>
</tbody>
</table>

This section evaluates the quality attributes, which the RefIOC should fulfill, based on an experience-based assessment[49], [50]. It is possible to check some quality attributes through the architectural decisions taken in the reference architecture. Using the layered, decomposition and service-oriented architecture styles are the most prominent architectural decisions in our reference architecture:

“The layered style puts together layers (groupings of modules that offer a cohesive set of services) in a unidirectional allowed-to-use relation with each other” [51]. In RefIOC, the layered style groups the subsystems at the external, conceptual, and internal layers.
By using a layered style, RefIOC promotes the quality attributes of modifiability, integrability, portability, and interoperability[51]. The layered style may cause a decrease in performance because it requires communications to take place only between neighbouring layers.

The decomposition style decomposes a system as modules and submodules and partitions the system responsibilities across them [51]. At each layer of the RefIOC, the identified subsystems provide services that do not overlap with the remaining subsystems at this layer. As indicated in [51], the decomposition style supports modifiability, integrability and applicability qualities in a system. As a trade-off, the decomposition style does not support performance.

Service-oriented architecture is an architectural style that uses loosely coupled services, which have separated concerns [52]. SOA promises modifiability, integrability, interoperability, flexibility, portability, reusability, loose coupling, and protocol independency of services. In addition, because several instances of a single service can run on various servers simultaneously, this enhances scalability and availability of the service.

As discussed in Section 1.3, the RefIOC-compliant system and all available partners’ Web services are deployed on an ESB platform. ESB is an open standards-based distributed synchronous or asynchronous messaging middleware that provides secure interoperability among partners’ systems. It promotes agility and flexibility with regard to high-level protocol communication between systems. Additionally, the scalability and availability are the attributes that can be achieved by using several instances of an ESB to provide increased throughput (scalability) and eliminate single-points-of-failure, which is the key objective for highly available systems.

The security quality is addressed in RefIOC through the introduction of the Business process modeler subsystem which realizes the Business process projecting service. This service specifies selected internals of the conceptual level specification of a process (a projection of the business process specification) to the outside world. This way, the IOC’s participants doing the local business process can hide their internal details from the outside world.

Performance of the RefIOC is important because partners need an acceptable response time in electronic business collaboration. The trade-off points are mainly related to performance of a RefIOC-compliant system:

- The choice of layered style for structure of RefIOC supports modifiability, interoperability, integrability, and portability but has negative effects on performance as it requires communication to take place only between neighboring layers.
- The decomposition style supports modifiability, usability, and applicability through modularization while this is detrimental to performance.

Furthermore, applying some essential subsystems affects performance of the RefIOC-compliant systems. For example, the Business process verification, Business process translator, and Business process state checker subsystems will require substantial computational power and are a potential bottleneck for the high performance of a RefIOC-compliant system.

The following cases promote the performance of the RefIOC-compliant systems:

- Definition of the external layer subsystems on a centralized platform affects the performance positively: one business process engine (Global enactment engine)
executes the global business process and synchronizes a number of other business process engines (Local enactment engines) that execute local business processes. 

• Usage of a small number of layers decreases the negative impact of this style on the performance quality.

For efficiency and effectiveness, it is desirable to have a highly automated RefIOC-compliant system; however, in reality; it is impossible. For this reason, the dedicated and interactive user interfaces are considered through which users can feed decisions to the appropriate application components. For example, in RefIOC, the user interfaces are considered for modelling business processes and rules, instantiating (and updating, if necessary) the global/local variables during execution, reasoning about verification results, feedbacking the current execution status with proposed actions, starting, pausing, and stopping the enactment of the business process, and so on. Of course, the knowledge in the system is accumulated through IOC’s life cycle, such that the automation level of successive IOCs can increase over time.

6. Conclusions

In current highly competitive global business environments, collaboration is no longer an option but a necessity for the organizations that want to survive on the market. To provide a complete automated end-to-end support of IOCs, a complex distributed architecture is required to stretch across many distributed and autonomous parties with heterogeneous local systems. According this, in this paper, we offer a distributed service-oriented reference architecture for IOCs support system that covers both the establishment and management of collaborative networks systematically. Reusing the knowledge (structure and requirements) contained in the proposed reference architecture leads to the reduction of efforts and time in the development of new inter-organizational collaboration systems.

References


A Reference Architecture for Automation … M. Mollahoseini Ardakani, S. M. Hashemi, M. Razzazi


Appendix A. Brief description of the CrossWork modules

In this section, we describe the tasks of each module shown in the CrossWork conceptual architecture of Figure 3.

In the external level, the Goal decomposition module decomposes the order specification into a set of components/primary services. The Team formation module finds a set of candidates for each service identified in the previous module, and selects from these to create candidate teams, and choose in each the most appropriate. In the following, the Workflow composition module constructs a global workflow model from the composition of publicly visible processes of the team members. The main goal of creating this global workflow was to coordinate the local workflows of the team members. Workflow verification module ensures that a composed global workflow contains no errors, and Workflow prototyping module verifies the functionality of the global workflow model by running the execution scenarios in a simulated environment. Also, the Transaction verification module verifies the transactional behavior of the composed global workflow. After verifying the global workflow, the Contract establishment module defines the rights and obligations of collaborating partners in a legal sense, and the Contract monitoring module monitors the commitment of partners to their agreements during enactment time. The global business process is next enacted by the Global enactment module. If for any reason, it was recognized that the global process needs to be changed during its enactment, the consistency of the new global process definition with the old process must first be checked. In CrossWork architecture, this responsibility has been delegated to the WF state checker module. The Global/Local transaction management modules are used to safeguard the reliability of processes [5].

In the conceptual level, the Process design module supports the design of the local business processes within a specific IVE member and takes place at the conceptual level. A projection of the local business process is then mapped onto the external level for use within the Team formation module [5].

The Local enactment module executes the local business process definitions owned by the members of an IVE. Furthermore, this module informs the Global enactment module about the status of the execution of the local process definitions. Finally, the Legacy integration module provides a common interface to execute operations in multiple, heterogeneous enterprise information systems. As the Local enactment and Legacy integration modules depend on the infrastructure existing at specific IVE members, these modules are placed at the internal level [5].
Appendix B. Brief description of the ECOLEAD subsystems

The tasks of each subsystem shown in the ECOLEAD conceptual architecture of Figure 4 are described in this section.

The Membership and structure management subsystem supports the registration, integration, disintegration, accreditation, rewarding, and categorization of VBE members, and the Profile and competency management subsystem supports the creation and maintenance of profiles/competencies for VBE members, the VBE itself, and the VOs registered within the VBE. The Ontology discovery and management subsystem aims to achieve objectives such as: (1) providing common understanding of the VBE-related concepts for all VBE actors, (2) facilitating the reusability of knowledge accumulated in one VBE with other VBEs, and (3) supporting knowledge interoperability both intra-VBE and inter-VBEs. Trust management subsystem aims to assist variety of VBE users with handling tasks related to the management of trust among organizations in the VBE. Decision support subsystem provides services, which support the monitoring of certain indicators in the VBE and issuance of notifications and warnings. This subsystem covers the following areas in VBEs: warning for lack of performance, warning for emerging VBE competency gap, and warning for low organization’s trustworthiness. VO information management subsystem stores information on created VO’s in the VBE profile. This information is used as experiences for creating new VOs. Bag of assets management subsystem supports the manipulation of the collection of common interest and useful assets (such as sharable documents, common software tools, lessons learned, VBE policies, etc.) in the VBE. Support institutions management subsystem manages the information about the related supporting institutions, e.g. insurance companies and training institutes [6].

The box in the center of Figure 4 reflects a set of subsystems, which are implemented to support the creation and configuration of a VO.
Appendix C. Brief description of the eSRA components

Table 4 summarizes the tasks of each component in the eSRA reference architecture.

Table 4. Brief description of eSRA components

<table>
<thead>
<tr>
<th>System layer</th>
<th>First refinement component</th>
<th>Second refinement components</th>
<th>Description [12]</th>
</tr>
</thead>
<tbody>
<tr>
<td>External layer</td>
<td>eSourcing_Middleware</td>
<td>Coordination_Interface</td>
<td>Provides a façade for protecting a collaborating party from malformed or malicious input from attackers, prevents disclosure of internal business process-details or other information when an exception occurs, and provides a sole communication channel to the counter-party, so, prevents accessing the internal domain.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contracting_Client</td>
<td>Provides support for the management of an e-contracting process.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global_WFMS</td>
<td>Enacts the contractual (global) business process.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Global_Rules_Engine</td>
<td>Manages dynamic business logic in the Global_WFMS by separating the implementation logic with exposing rules.</td>
</tr>
<tr>
<td>Conceptual layer</td>
<td>Translator</td>
<td>Rules_Modeler</td>
<td>Exchanges information after a format transformation between the external- and internal layer for reconciling the business-, conceptual-, and technological complexity of systems involved.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process_Modeler</td>
<td>Allows to model different business rules types related to local business processes, namely integrity-, derivation-, reaction-, and deontic rules.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Workflow_Composer</td>
<td>Supports for the conceptual modeling of local business processes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Verifier</td>
<td>Constructs a composite global business process from involved local processes.</td>
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<tr>
<td></td>
<td></td>
<td>Simulator</td>
<td>Before enactment, verifies the collaboration configuration from different perspectives: control-flow, data-flow, resources, transactional properties, etc.</td>
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<tr>
<td></td>
<td></td>
<td>Pattern_Knowledge_Base</td>
<td>Stores conceptually formulated patterns organized in a taxonomy belonging to different perspectives such as control-flow, data-flow, and exception management. It also stores implementations of respective patterns in industry standards such as BPEL, BPMN, etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rules_Repository_Manager</td>
<td>Stores/manages business rules for rapid rules modeling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process_Snippet_Manager</td>
<td>Stores/manages process parts for rapid business-process assembly.</td>
</tr>
<tr>
<td>Internal layer</td>
<td>eSourcing_Setup_Support</td>
<td>Local_WFMS</td>
<td>Enacts the local business processes of partners.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Process_Data_Manager</td>
<td>When the partner processes are enacting by Local_WFMS, this component provides/manages the required data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Production_Data_Manager</td>
<td>Stores/manages the production data.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local_Rules_Engine</td>
<td>Manages dynamic business logic in the Local_WFMS by separating the implementation logic with exposing rules.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rule_Data_Manager</td>
<td>Provides/manages the required data for Local_Rules_Engine.</td>
</tr>
<tr>
<td>Trusted Third Party</td>
<td>Web_Service_Wrapping_Legacy_System</td>
<td>Extends the business logic of the local legacy systems so that they can be installed and run as web services.</td>
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<tr>
<td></td>
<td>Identity_Management</td>
<td>Prevents an exchange with parties who lack trustworthiness and reputation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reputation_Management</td>
<td>Checks the reputation of potential collaborating counter-party.</td>
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</tr>
<tr>
<td></td>
<td>Brokering_Service</td>
<td>Arranges transactions between a buyer and a seller for a compensation that involves the matching of the contractual spheres of counter-parties.</td>
<td></td>
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<tr>
<td></td>
<td>Bidding_Service</td>
<td>Coordinates the set of trading rules for the exchange of buying and selling services through bids and awarding a sale to the highest bidder.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Validator</td>
<td>Verifies the business processes of the collaborating parties for correct termination and inheritance relations.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Process_Snippet_Manager</td>
<td>Stores process parts for rapid business-process assembly.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D. Brief description of SUDDEN subsystems

Table 5 shows a brief description of each subsystem shown in the SUDDEN conceptual architecture of Figure 7.

<table>
<thead>
<tr>
<th>SUDDEN subsystem</th>
<th>Description [8]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handle business opportunity</td>
<td>The subsystem is responsible for creating a business opportunity (in the form of a well-formed description of an Abstract Supply Network), advertising (where and as appropriate) and (possibly collaboratively) resolving it.</td>
</tr>
<tr>
<td>Collaborative planning</td>
<td>The subsystem is responsible for clarification of goals, processes, and responsibilities among a consortium that is engaged in a business opportunity prior to the automated support provided by SUDDEN.</td>
</tr>
<tr>
<td>Team formation</td>
<td>The subsystem is responsible for taking an abstract supply network and generating a ranked list of candidate teams for it.</td>
</tr>
<tr>
<td>Ranking</td>
<td>The subsystem is responsible for the evaluation of candidate teams for a given abstract business opportunity.</td>
</tr>
<tr>
<td>Coordination</td>
<td>The subsystem involves identifying and coordinating the interdependencies of the set of services within the abstract supply network.</td>
</tr>
<tr>
<td>Performance measurement</td>
<td>The subsystem allows evaluating the performance for a concrete supplier or a set of suppliers/enterprises.</td>
</tr>
<tr>
<td>Coordination fit</td>
<td>The subsystem is responsible for taking a given abstract supply network and candidate team(s) for that network and analyzing how well the team functions as a team.</td>
</tr>
<tr>
<td>Supplier development</td>
<td>The subsystem is responsible for supporting suppliers to understand their current competence, identify missing or underdeveloped competences and provide support for identifying means for development to improve competences.</td>
</tr>
<tr>
<td>Network exploration</td>
<td>This subsystem allows browsing the network of registered organizations, users and their projects.</td>
</tr>
<tr>
<td>User &amp; organization management</td>
<td>The subsystem provides the possibility to register organizations/users, to view, update or modify their associated profile.</td>
</tr>
<tr>
<td>Competences management</td>
<td>The subsystem manages the roles’ entities, defined for the different COs in the system and deals with repositories of entities associated to competences and the underlying functionality.</td>
</tr>
<tr>
<td>Service management</td>
<td>The subsystem provides the data structures that allow a search across concepts of product, production process, material and supporting services, and machinery used for realization.</td>
</tr>
<tr>
<td>Templates (process, contract, WBS)</td>
<td>The subsystem is essentially a repository for proforma processes and structures, such as process, contract, and WBS.</td>
</tr>
<tr>
<td>Knowledge &amp; data management</td>
<td>The subsystem essentially acts as a repository for concrete processes and (conceptual and data) structures.</td>
</tr>
<tr>
<td>Legacy systems integration</td>
<td>The subsystem is responsible for providing a common interface to execute operations in several and heterogeneous enterprise information systems.</td>
</tr>
<tr>
<td>Execution feedback</td>
<td>The subsystem is responsible for monitoring the performance of a chosen team of suppliers during the execution the planned business opportunity.</td>
</tr>
</tbody>
</table>