Addressing Interoperability Issues in Business Process Management

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***Abstract*— As part of the INTEROP NoE first phase work, interoperability requirements and existing facilities on the area of Business Process Management were studied. This paper summarizes the contributions and discusses current research trends.**

Business Process Management is seen as a set of continuous processes in an enterprise related to the strategic decisions, production and delivery workflows, IT support, and evaluation of the appropriateness and performance of the workflows.

As enterprises are under increasing pressure to be agile for collaboration, interoperability and external business processes with partners in a joint business network become essential. On this area, a definite requirement for moving from case-by-case IT integration projects to more flexible unification-based or federation-based solutions can be seen. At the same time, interoperability challenges rise from the success of technical message transfer, through semantics preservation needs (information representation formats, information contents ontologies), to conformance to the joint processes and process-awareness. Furthermore, pragmatic aspects related to business values, business rule, and contractual prioritizing complicate the issue.

Two complementary development strategies push the area forward: standardization within various consortia, and research on common infrastructure services for process model management, interoperable process management, and interoperable sharing of services.

I. Introduction

Business Process Management is seen as a set of continuous processes in an enterprise related to the strategic decisions, IT support, workflows on production and product delivery, and evaluation of the appropriateness and performance of the workflows.

The globalization of business and commerce makes enterprises increasingly dependent on their cooperation partners. At present, competition takes place between networks of enterprises, instead of between individual enterprises. In the inter-enterprise collaboration context, business processes are divided into two categories:

- external (public) processes, i.e., processes performed in collaboration with customers, suppliers and other partners; and
- internal (private) processes, i.e., processes performed at enterprise's own ICT system, possibly using workflows to execute the task.

As enterprises are under increasing pressure to be agile for collaboration, interoperability and external business processes with partners in a joint business network become essential. On this area, a definite requirement for moving from case-by-case IT integration projects to more flexible unification-based or federation-based solutions can be seen.

Interoperability, or capability to collaborate, means effective capability of mutual communication of information, proposals and commitments, requests and results. Interoperability covers technical, semantic and pragmatic interoperability. Technical interoperability means that messages can be transported from one application to another. Semantic interoperability means that the message content becomes understood in the same way by the senders and the receivers. This may require transformations of information representation or messaging sequences. Finally, the pragmatic interoperability captures the willingness of partners for the actions necessary for the collaboration. The willingness to participate involves both capability of performing a requested action, and policies dictating whether the potential action is preferable for the enterprise to be involved in.

Facilitating interoperability of activities of Business Process Management must be seen in the context of collaborative systems, and thus interoperability supporting architectures and platforms.

As part of the INTEROP NoE first phase work, interoperability requirements and existing facilities on the area of Business Process Management were studied [1]. This paper summarizes the contributions and discusses current research trends. This paper first discusses the goals and activities of business process management in Section II. Section III gives an overview of the research results reported for the state-of-the-art analysis. These are then reflected in the context of interoperability architecture approaches in Section IV. We conclude by future interoperability challenges of BPM.

II. Business Process Management activities

According to the BPMS (business process management systems) paradigm, which was firstly introduced 1995 [2], continuous Business Process Management consists of five core processes [3]:

- Strategic Decision Process,
- Re-Engineering Process,
- Resource Allocation Process,
- Workflow Process, and
- Performance Evaluation Process.

A corporation defines itself by its products and services. Business processes describe the way they are produced, delivered, maintained etc. For the execution of its business processes a company requires two main resources: employees – in the following designated more generally as organizational structure – and information technology (IT). This leads us to four core elements of corporations: products, business processes, organizational structure, and IT.

The Strategic Decision Process takes place after a strategic decision has been made for the (re-)engineering of an enterprise's organisational environment. Based on global objectives, constraints for the processes to be selected are stated and success factors are recommended. The business processes are selected and the re-engineering objectives are defined. Furthermore, the activities of initial information gathering and analysis concerning the selected business processes take place.

The primary objective of the Re-Engineering Process is to design the new business process. Modelling constitutes a significant part of this BPMS subprocess, since the business process model to be generated has to be unambiguously defined, to further facilitate the execution of the following BPMS subprocesses. The designed business processes will have to conform with the evaluation criteria set in the Strategic Decision Process. Design takes place in an iterative way in order to obtain the best feasible results for the business process, keeping in mind all constraints relative to the business process, which might be imposed and affected by invariable factors. The Re-Engineering Process can be supported by a number of techniques, for instance modelling, simulation, animation, characteristic index calculation etc. It can be further enriched by the actual use of new information technology as an enabler and facilitator. In any case, the Re-Engineering Process has to cover human resource management issues, which might appear.

The primary objective of the Resource Allocation Process is to enable identification and coordination of resources, and realization of the business processes (designed during the Re-Engineering Process). These resources are mainly related to Information Technologies, for instance, existing legacy applications might be modified, new applications might be implemented. All resource requirements should be readily derived from the results of the Re-Engineering Process. The primary objective of the Workflow Process is the execution of the re-engineered business process, using resources made available during the Resource Allocation Process [4]. After test runs and additional corrective actions the process is executed in "real" time and location. This execution generates information necessary for the Performance Evaluation Process which follows. The primary objective of the Performance Evaluation Process is the qualitative and quantitative evaluation of all information obtained by the realization and execution of the business process. These results constitute an invaluable feedback for both the Strategic Decision Process and Re-Engineering Process.

III. State of the Art

Business Process Management Systems (BPMS) have become a core concept in designing, developing, deploying, and maintaining business applications. Likewise, workflow technology has proved to be an indispensable aid to speed up process-oriented application development. The state-of-the-art report [1] discusses the lifecycle of business processes (workflows) in steps of design, enactment, static and dynamic management, and static and dynamic analysis of business processes adequacy.

The design phase involves business process modeling, verification and analysis. The CASE tools that were brought up for the SOA produce artefacts like business models (targeted to humans understanding the enterprise workings), workflow models (intermediate between levels), and executable models (detailed enough to be run on the actual system).

The languages listed and described in the document include modeling languages such as UML [**?**], PSL/PIF [5], [6], IDEF [7], BPMN [8], XLANG [9], WSFL [10], ebXML [11], BPEL4WS [12], WPDL [13] and XPDL [14]. Shared concepts to these languages are focusing on tasks and sequencing of them; processes are described as exchanges of control triggers and messages and participants as collections of tasks they are capable and responsible of performing. Languages like UML have originally been more oriented towards implementing collaborative processing, while some newer ones like XPDL focus on modeling the synchronizing messages between autonomously proceeding processes. Another summary can be found on [15].

Depending on the supported language and the intended target of the models written or drawn, verification of those models can be performed. Analysis techniques for specification properties have long traditions and can be readily adopted to business process verification. Many of the language specifications also include statements on well-structured or well-defined models, thus giving hints for ruling out structurally inconsistent models (e.g., modeling pattern used with incorrect number of participants, livelocks, deadlocks). Verification methods based on Petri nets have been addressed [16]. Information flow analysis is a less addressed area [17]. Furthermore, temporal constraints are of high importance in business processes, and need to be explicitly modelled and analyzed [18].

A set of tools with a supporting specific language are also introduced, covering BizzDesigner with Amber language, ARIS tool and language, MEMO methodology, tool and language, and ArchiMate.

BizzDesigner is a process, organization, and data modeling tool with a model management repository and basic model operations. It is accompanied with a waterfallish methodology for (re)designing processes. The Amber language is targeted for business consultants and organization modelling, thus missing architectural perspective of information systems [19].

ARIS [20] is intended to serve documentation of existing business process types, blueprint for analysing and designing business processes and support for the design of information systems. It is targeted for system designers. ARIS supports decomposition of an enterprise to data view, function view, organization view , and connective control view.

MEMO [21] is an object oriented methodology and a tool for the analysis and (re-)design of business information systems. MEMO distinguishes perspectives of strategy, organization, and information systems with aspects of structure, process, resources, and goals. In the methodology, four types of domain analysis are described: feasibility, strategic analysis and (re-)design, organizational analysis and (re-)design, and information analysis.

The ArchiMate project [22] provides concepts and techniques to enterprise architects in the visualization, communication and analysis of integrated architectures. The ArchiMate language facilitates interoperability among various types of languages and pays attention to modeling relationships between the more detailed models. The language covers business, application and technical infrastructure layers of an enterprise, as well as relations between these layers.

More generally, we can state that tools differ in their assumptions on the architecture of the enactment environment, for example, whether is it centralized or distributed, and on the expected output (generating application code, or controls for the overall external process control flow), and the level of detail enforce by the target platform and granularity of task provided by the controlled business applications.

Enactment involves making the process model executable and the actual execution of applications in conformance to the business process model. Here, different approaches are used:

- abstract execution of the model,
- generation and execution of code,
- allowing autonomous services to perform specified tasks and interact, but monitoring the activity externally and reacting to exceptions.

For the execution of the workflow models, BPM system standards – WfMC [23] – and some open source BPMS solutions [24], like Petri net based YAWL [25] and Java-based jBPM [26].

The inter-enterprise aspects are well-presented also in the projects from Loria, VITA Nova, and CMI. Multi-partner business process management (inter-organizational processes) have been under study and development in Loria for several years, gaining experience with architects and car builders and their suppliers [27]. Healthcare architecture from Sweden [28] introduces VITA Nova, where collaborating process managers coordinate inter-organizational processes. A process manager is responsible of message broker duties, such as handling conversions and messaging across IT systems, of measuring and optimizing the process during operation. CMI (Collaborative Management Infrastructure) [29] introduces an architecture for inter-enterprise workflows, based on CORE engines. The CORE engine provides primitives for coordination and awareness, like defining resources, roles and generic state machines. The architecture extends the traditional workflow model by placeholder activities that are dynamically replaced at runtime.

The execution and implementation infrastructures should provide for interoperability at four different levels [30]. In the bottom, connectivity at the network level is required for technical interoperability. Second layer captures communication between applications, preserving semantic interoperability, i.e. contents of messages and information within exchanged documents. The third layer involves collaboration between people or applications, and coordination of business processes. At this level, some coordination standards start appearing, like ebXML and WSDL. At the topmost level, enterprises need ways of finding new partners, and of negotiating and closing contracts.

In the enactment environment we find two aspects especially important: the types of abstract processing steps (ACID transactions, long-lived business transactions with compensation routines, service invocations without transactional semantics), and the type of communication support required from the potentially heterogeneous working environment. In addition, the enactment phase involves detection and recovery from exceptions and needs for emerging behaviour. The management phase is partially overlapping the enactment phase: it deals with partnership, resource allocation, management of NFA aspects, communication channel management including transparencies like mobility transparency,

Business process management will require management of dynamic business change. This causes requirements on more adaptive technology for process execution, like requirements of using late binding, rule engines, and adaptive processes for dynamic change during execution.

For the adaptive requirements, contract-based systems are applicable, and a variety of projects on contract-based virtual enterprises (extended enterprises, eCommunities) are under way.

eFlow [31] is a platform that supports specification, enactment and management of composite services. The service process engine responsible of enactment is composed of the scheduler, the event management and the transaction mangers. A service process broker is used to discover the actual services that can fulfill the actions required.

Tilburg University works on contract-driven coordination and transaction management [32].

From the Business Process Integration and Automation (BPIA) perspective, autonomy of enterprises correlates to the fact that the systems being integrated have their own process choreography engines and execute internal business processes privately. Hanson et al. suggest a general-purpose conversation support as a solution for business process integration [33]. Their approach separates interoperability support from business processes, for the reasons of enterprise sovereignty, different timescales of business process and interoperability technology changes, and ease of modification of business processes.

The Web-Pilarcos project [34] develops B2B middleware services for inter-enterprise collaborations. A central element in the architecture is that of eCommunity contract, that captures interoperability aspects at various levels of modeling or abstraction. The range of elements reflects the ODP viewpoint concerns. The collaboration environment proposed supports two phases for eCommunity lifecycle: a breeding environment where discovery of potential partners is supported by an enhanced trading service and static interoperability tests, and an operational environment supported by monitoring and enactment of enterprise applications.

WISE (Workflow-based Internet SErvices) [35] addresses process definition, enactment, monitoring and coordination in a virtual enterprise setting. The process definition component allows composition of virtual business processes from building blocks published by partners. The process model is then compiled for enactment. The process monitoring provides information for load balancing, routing, QoS, and analysis purposes.

CrossFlow [36] uses contracts as a basis for cooperation management. The key element in the architecture is a trader or matchmaking engine that matches contract suggestions and request from potential partners. Based on the specifications in the contract, a dynamic contract and service enactment infrastructure is set up.

The platform assumptions determine much of the BPM cost and the dynamism of the resulting eCommunity. Some examples of the transaction-oriented processes in are given in PRODNET [37], an agent-based system is discussed in MASSYVE [38], and a service-federation approach is found in FETISH-ETF [39]. Although the life-cycle of an eCommuity can be divided into formation phase, operational phase, and dissolution phase, the membership negotiations are not always restricted to the formation phase.

Beyond these life-cycle steps we need to consider the mechanisms using facilities for design, enactment, management and analysis. These can be centralized solutions, or in case of virtual enterprise environments, supported by distributed systems in themselves. These environments address aspects like partner selection, collaborative business process definition or negotiation, mapping to platform services, and collaboration contract management. A survey on various virtual enterprise approaches and different model aspects can be found in [40].

Finally, the analysis phase involves collection of data about performance, usability, and exception situations, so that the business process models can be further improved. The report addresses the need of defining key performance indicators, addressing as well operational, tactical as strategical level of business processes. A well-known method for strategical needs is Balanced Scorecards (BSC) [41]. In the analysis phase, also tools for animation of enterprise and business process models come into the picture [42].

IV. Collaboration architectures

For understanding the practical consequence of the BPMS paradigm and activities, the inter-enterprise BPM activities need to be considered within the framework of collaboration architectures. Different architectural approaches to inter-enterprise collaboration can be taken: integrated, unified or federated. Each approach focuses on a different method of ensuring interoperability between local business processes and or in other terms, the consistency of collaboration within an external business process.

Integrated approaches build collaboration on a technical integration foundation. These approaches ensure interoperability by using shared execution environments and shared communication conventions. Integration aspects include processing platform integration, data integration and portal solutions. We can distinguish between the integration of full enterprise systems, covering workflows between enterprises (integrated ERPs, distributed workflow systems) and application integration (A2A).

Unified approaches build collaboration on independent interpretations of the shared model of business. These solutions ensure interoperability by using shared metamodels and concepts, and shared specification environments. Traditional solutions, like EDI, trust on standardized shared models of communication and computing, and on software developed in accordance to those standards. The drawback of such systems is in the expensiveness of maintenance and evolution of systems and services.

Federated approaches establish and maintain collaboration between autonomous local services, each of which runs a local business process. The interoperability between these services need to be addressed from information exchange and processing aspects; relevant is also the semantics of the external, joint processing. With the federated approach, it is possible to truly address the dynamic nature of collaboration and evolution requirements. For federated (or in some cases, unified but dynamic) solutions we can take up virtual enterprises (B2V). The inter-enterprise collaboration is formed in an environment that is able to support discovery of new partners, as well as the verification of interoperability between them.

As we go from integrated to federated approaches, the scale of dynamicity of the collaboration and use of metalevel infrastructure services for maintaining the interoperability increases. The focus of methods used for integrated and unified architectures is in the modelling, design and deployment phases of the system; while the focus for federated approaches by necessity is moved towards an operational time management environment.

The interoperability approach at the external business process level is further reflected to the requirements for enactment and communication infrastructure too. Integrated systems require integration solutions at all layers; the infrastructure use same technical, semantic, and pragmatic solutions in all enterprises. The unified approaches are currently the topical ones: the shared process model is implemented over a heterogeneous platform using differing transformations like in MDA. The federated approach minimize the needs of shared solutions at the implementation and execution infrastructure level. However, these approaches require additional high-level services to ensure process-aware interoperability at all. The benefits of contract-based solutions lie in the loose coupling of services, which in turn is necessary for autonomy preservation. The contracts involved need to include agreement on information flows, abstract processing, business rules agreed on, and make room for exceptional or emerging behaviour. Both agent-bases solutions and open service market systems are suitable examples of federated approaches (example projects, see [43], [44]).

As shown by the approaches described in Section III, the interoperability challenges can be tackled with different tools depending on the general interoperability architecture.

Essentially, enterprise interoperability architectures address, or can address, an enhancing set of the following services:

- Facilitating communication. The basic aim for communication is to share information. Any practical communication will be based on some concrete representation of information, and some concrete mechanism of signaling the information. In practice, networking system designers provide models of communication channels that determine the assumed contract of form for exchanging information. This level deals with technical and semantic interoperability.
- Facilitating abstract processing. The basic need in collaboration is to distribute (partition) the load of information processing. In practice, the proposals and commitments on processing need to be expressed in a computing platform independent way. This brings us to service oriented architectures (SOA). This level deals with technical and semantic interoperability.
- Facilitating process-aware collaboration. The collaboration itself needs to be manageable, which means that the systems should have facilities for expressing collaborative processes and assigning processing and communication steps to them. This level deals with semantic and pragmatic interoperability. Various exceptional situations in collaborations may rise so called emerging behaviour in the collaborating system; these aspects can only be managed by process-aware approaches and considerations of pragmatics.
- Facilitating evolution at the collaboration partners independently. In practice, isolation from technologies by service oriented approaches and late binding over abstract communication channels give fairly good status. In addition, repositories and ontologies for matching and retrieving current information.

In this context, the still open business process management challenges fall essentially in to the categories of process-aware collaborations, and evolution support. Furthermore, the inescapable need for preserving autonomy of enterprises has to be addressed.

Autonomy covers issues like

- selection of computing platform, and schedule of technical changes in it,
- selection of service components put externally available,
- evolution lifecycle of each offered enterprise application,
- including withdrawal of services already part of some collaboration,
- decisions on the kind of collaborations that are entered, in terms of external business processes,
- decisions on the kind of partners are accepted for these collaborations, and
- decisions on leaving existing collaborations.

The general trend seems to drive towards unified (like MDD) or federated approaches with rigorous set of infrastructure services for interoperability support. Interoperability facilities include an abstracted communication architecture with transaction support and (re-)negotiable QoS etc. It also include facilities for statically verifying behavioural interoperability and preservation of information semantics in the collaboration. Furthermore, operational time monitoring of the conformance to an explicitly negotiated contract on the collaboration – including an external business process model to follow – is a commonly accepted need.

V. Conclusion

The focus of traditional workflow management systems is on enactment of processes [45], giving less support for diagnostics, simulation, and collection and interpretation of real-time data. Furthermore, few workflow management systems have supported simulation, verification and validation of process design.

It has been shown that current workflow and coordination systems are not flexible enough to support the needs of cooperative, virtual enterprises. The needs are essentially as follows:

- respect of the autonomy of each partner (public/private),
- coordination of complex interactions existing in a multi-partners context (services composition/orchestration, advanced transactions models,etc.);
- use of widely accepted technologies in order to facilitate the integration and the interoperability,
- composition and integration of processes or process fragments, and control of the overall process by contracts monitoring.

It cannot be assumed that all potential runtime interactions could be predefined. Thus, a generic interoperability protocol is fundamental for agreeing on a choreography, assigning, invoking and terminating.

The shared collaboration models evolve over time and changes are needed. For semantic interoperability, various ontologies can be used for matching together similar services, and similar information contents. The relationship between enterprise modeling, ontology-based infrastructure services, and business process management is still under further study, although a number of interesting projects are under way or emerging.

Considering the computing platforms on which business processes and workflows are collaboratively executed, the service oriented architecture approach (SOA) is an essential step forward [46]. It gives tools for isolating local implementations of tasks and local business processes, with tools for making metainformation available about the elements provided for external business processes. Enhancements to the basic architecture already introduce languages and tools for modeling cooperative, abstract processes. Further work is however needed on adding strategical, operational, and tactical guidance to these models; the contract-based interoperability architectures provide good environment for intertwining these non-functional aspects in to the functional basic models.

When entering the field of business process modeling (BPM), one is confronted with an overwhelming number of tools and modeling languages. Often these languages and tools have very little in common. In most of the cases, the conceptual domains that are covered differ from language to language. Some emphasize elements of workflow in the models, others concentrate on quantitative analysis, again others try to integrate business processes and supporting information technology. Moreover, software tools are an important success factor for a language; some of the most popular languages are proprietary to a specific tool. It is clear that none of them has succeeded to become "the standard language". Overall, there are a number of aspects on which almost all of these languages score low:

- the relations between domains (views) are poorly defined: the models created in different views are not integrated;
- most languages and notations are not standardized;
- many languages have a weak formal support;
- most languages miss the overall architectural vision on en enterprise;
- most of the business process modeling languages focus on modeling the internal business processes and pay little attention to interoperability issues.

As enterprises are under increasing pressure to be agile for collaboration, interoperability and external business processes with partners in a joint business network become essential. On this area, a definite requirement for moving from case-by-case IT integration projects to more flexible unification-based or federation-based solutions can be seen. At the same time, interoperability challenges rise from the success of technical message transfer, through semantics preservation needs (information representation formats, information contents ontologies), to conformance to the joint processes and process-awareness. Furthermore, pragmatic aspects related to business values, business rule, and contractual prioritizing complicate the issue.

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