A Design Methodology for B2B Systems
Case of an e-Procurement System

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Abstract: As corporations rely more on collaboration with partners to enhance their position in the business world, they transcend their traditional information system boundaries. They use IT-based inter-organizational information systems (B2B systems - Business to Business) as a powerful strategic tool to link with their partners in their supply chain. The B2B systems are critical for businesses in the current intensive and competitive market. By considering the concepts of inter-organizational business process (IOBP), this paper proposes an MDA-based methodology for B2B systems development which relies on the principles of BPM (Business Process Management) and SOA (Service Oriented Architecture). Thus, our methodology considers three levels in a top-down manner: collaborative business (organizational), business process (conceptual) and process execution (technological). We have proposed an UML AD profile for IOBP modelling. Then, the specific partner's processes are derived based on MDA-based model transformations. Finally, the B2B interactions are represented using Web services technology. In addition, we validate the practicability of our methodology with the implementation of an e-procurement system.

1 INTRODUCTION

On the Internet, B2B (business-to-business) is the exchange of products, services, or information between businesses rather than between businesses and consumers. In the new business era, B2B systems are becoming a competitive necessity due to globalization and the growing importance of business alliances (networked organizations, extended enterprises, etc.). They are the most common form of technology to support data and knowledge exchange between business partners like in e-Procurement systems (Dorn et al., 2007). The potential benefits of e-Procurement are transaction cost savings and competitive sourcing opportunities. It also increases the bargaining power of the buying organization, which now has a better information visibility of its business processes. Moreover, the strategic value of B2B systems has been well recognized for its real-time interaction, higher transaction accuracy, more efficient and quicker payments, rapid response, reduced search costs, reduction in inventory and tighter links to customers (Medjahed et al., 2003). These benefits enable all parties to have high operational efficiency and capability, and more and more corporations tend to adopt B2B systems in order to gain competitive advantages. IOBP are the enabler of such business environments. Henceforth, there is a need for supporting IOBP that interacts with the existing business process of individual organizations.

Consequently, modelling such systems that span multiple organizations involves new challenges, mainly the ability to cope with autonomy, privacy, distribution of components owned by business partners to support the joint execution of collaboration which requires the support for coordination through mutual agreements (Bouchbout et al., 2011). For this purpose, by considering concepts of BPM and SOA, we present an MDA-based design methodology for development of B2B systems. It provides the capability to represent and model IOBP independent of notation, standard or technology.

The remainder of the paper is structured as follows. In section 2, we cover the basic concepts of IOBP. Section 3 highlights the related work for B2B systems methodologies. Subsequently, the section 4 describes the aspects of the proposed methodology. The section 5 assesses the capabilities of the proposed methodology. Finally, the paper finishes

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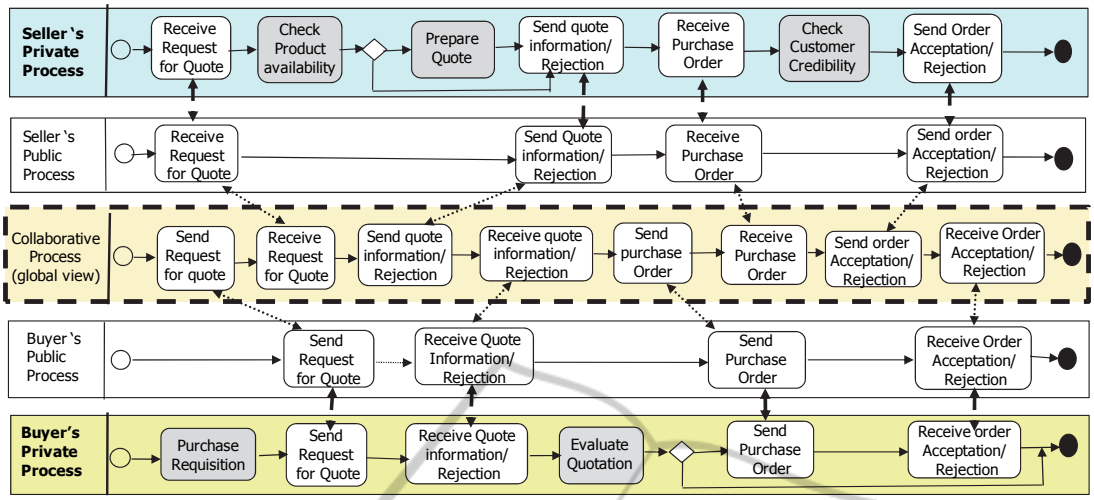

Figure 1: Basic scenario of e-Procurement: Collaborative, Public & Private processes.

giving a summary and an outlook to future work.

2 INTER-ORGANIZATIONAL BUSINESS PROCESS

Recently, IOBP which depict the nature of business interactions (information exchanges) between organizations are turning to be an important issue of contemporary BPM. To explain specifics of IOBP modelling, we will discuss their requirements.

2.1 Characteristics of Inter-Organizational Business Process

While intra-organizational processes comprise activities executed inside one organization only, the activities comprised in an IOBP are executed by different organizations that are working together to reach a common objective. Moreover, compared to intra-organizational business processes, IOBP is based on multiple data-sets, owned and maintained by the different involved stakeholders with the goal to interweave the existing partner processes whilst creating minimal impact on the existing processes (Chebbi et al., 2006). Furthermore, IOBP usually do not have a centralized control instance or process owner (Bouchbout et al., 2010). It depicts the different roles involved in the collaboration and their specific responsibilities with regard to the collaboration scenario. Hence, it needs close coordination among networking partners which requires an agreement on how to interact and exchange information, business documents and messages. Finally, the privacy and autonomy requirements are at the top priority of participant's organizations.

Furthermore, in order to make IOBP work, each involved organization has to implement not only its internal processes (private processes), but also its external behaviour (public process). So, adopting the approaches used by (Bouchbout et al., 2010); (Chiu et al., 2002); (Huemer et al., 2008); (Greiner et al., 2006); (Legner et al., 2008), we consider a process described either as a *Private* (orchestration, internal or executable), *Public* (local choreography, abstract or view), and *Collaborative* (global choreography, cross-organizational or inter-organizational) in order to better separate the information density of different areas of concern. The Figure 1 illustrates these process categories.

2.2 Inter-Organizational Business Process Modelling Languages

To couple processes in the development of an IOBP model is a complex task, as each business participant has its own "private" set of established modelling languages like UML2 Activity Diagrams (OMG, 2009), and BPMN (OMG, 2011). Important contributions to handling the specific modelling requirements of IOBP come from approaches for distributed Workflow management, e.g. (Aalst et al., 2001); (Chebbi et al., 2006); (Chiu et al., 2002), current extensions of process modelling (Seal et al., 2005); (Touzi et al., 2008), and B2B standards like ebXML BPSS (Medjahed et al., 2003), but has been limited to the process layer so far and they do not fulfil the inter-organizational interactions issues. This is so because they are incapable of representing

multiple actors participating in each collaborative task while keeping consistency of the overall processes. Moreover, one major requirement of business/IT specialists in practice is the ability of formal analysis and verification using Petri Nets (Girault 2001); (Aalst et al., 2010) of BPM languages like BPMN, EPC (Scheer, 1999) and UML. Finally, the possibility of execution code generation like BPEL and WS-CDL (Medjahed et al., 2003). However, UML Activity Diagrams, EPC and BPMN are more suitable to model public or private processes from the viewpoint of one partner instead of showing the peer-to-peer interactions between the partners as a whole. Hence, most of the languages provide insufficient support for modelling IOBP and do not offer a collaborative and integrated modelling framework comprising all levels of abstraction.

Having these considerations in mind, our approach provides an UML AD profile (Korherr and List, 2007) ensuring more expressive power for IOBP modelling, with the goal to develop a meta-model that covers comprehensive aspects of B2B business process theory including collaborations, interaction flow, partner's role, message exchanges, public and private activities (at a high abstract level).

2.3 Methodical Approaches for IOBP Modelling

In order to establish collaboration between business partners one may start "*bottom-up*" from the private processes or "*top-down*" from the IOBP (Bauer et al., 2008); (Chebbi et al., 2006); (Greiner et al., 2006) (Ziemann et al., 2007). In bottom-up approach, the technology drives the business. However, in top-down approach the business requirements drive the technology. A bottom-up approach bears the limitation that if each partner develops its public process in isolation, it is rather unlikely that their processes are complementary to each other. Thus, it works only, if one partner dominates the partnership and the other one adapts his interfaces accordingly. In this case, discovering potential business partners requires complex comparisons of public processes. The bottom-up approach implementations are based on Web services compositions (Peltz, 2003). In cases where private processes already exist, an organization could simply expose application functionality as a service and thereby realizes machine-to-machine process integration with its business partners.

In general, a top-down approach describes a decomposition approach where standards organizations, industry consortia or market leaders define an IOBP. Hence, a top-down approach commences with a global view on the collaboration efforts. The global view is described by an agreed model of an IOBP, which should be followed by the public processes of each partner. Each business partner is then able to derive its public process and to bind its private processes to the IOBP.

In this paper, we follow the top-down approach which is more appropriate for an e-Procurement system. This requires that the commonly agreed IOBP was defined before. Hence, our approach helps to develop public processes that are compliant to each other. This is guaranteed by the fact that each partner derives its public process consistently to a commonly agreed IOBP.

3 RELATED WORK

Before we present our B2B system design methodology, we will briefly refer to some related work in the following propositions done in the field of inter-organizational Workflows or B2B collaborations (Greiner et al., 2006); (Ziemann et al., 2007); (Huemer et al., 2008); (Legner et al., 2008); (Touzi et al., 2009), but it misses some research clearly addressing the B2B systems methodology.

Legner et al., (2008) have presented a method for modelling inter-organizational processes and deriving business services in three steps. A framework of conceptual inter-organizational business modelling is then defined containing a public process model which serves as reference for the participating organizations (Step 1). Then, the existing private processes have to be assigned and eventually aligned to the agreed public process model (Step 2). After that, the public process interface is realized by business services leveraging web service technology (Step 3). The business process model is used to derive XML-based business documents that are exchanged between business services. In addition, private process modules are transformed into workflows for business process automation which later can be implemented using the Business Process Execution Language (BPEL).

Huemer et al., (2008) have developed a methodology dealing with collaborative processes called UN/CEFACT Modelling Methodology (UMM). UMM specifies collaborative business processes involving information exchange in a technology neutral, implementation-independent manner. UMM is a UML modelling approach for global choreographies of B2B scenarios. It is a top-

down approach that makes use of worksheets to capture domain requirements. UMM do not provide a complete development process to generate IOBP executions. It only provides a development process for modelling technology-independent IOBP.

The work of Touzi et al., (2009), has proposed a model-driven approach to design a collaborative information system (CIS) dedicated to deal with exchanged data, shared services and collaborative processes. The CIS design crosses the different abstraction layers (business, logic and technological) and exploits at each level the associated models to build the models of the next level. The model of an IOBP is BPMN-oriented and based on the SOA. Its meta-model has been defined by referencing the BPMN specifications as well as the IOBP aspects.

The framework proposed by Ziemann et al., (2007) presents a method for the creation of collaborative process on a conceptual level. They described how cross-organizational business processes can be modelled and transformed to technical process models in the form of Web Service protocols. Their framework can be instantiated using EPCs (design phase) and BPEL (implementation phase) to describe models in different life cycle phases and demonstrated the transitions between these phases. However, a description of how organizational roles can be communicated to partners is missed.

Greiner et al.'s work (2006) describes the designing and the implementing of cross-organizational business processes including different levels of technical detail: the business level, the technical level and the execution level. They identify how the mappings and the transformations are needed among private process, view process and IOBP among the different levels. The business level models illustrate the organizational business aspects. The technical model secures the technical realization of the process integration and represents the bridge to the process execution.

Summarizing the above review of related literature, we observe that the issue of inter-organizational systems modelling and development has been extensively addressed. Yet, while the proposed solutions strive to enable the operation of an IOBP, no explicit consideration of generic business requirements is made to relate to generic inter-organizational scenarios. To achieve this we propose a design methodology for B2B systems development by combining MDA and SOA.

4 A DESIGN METHODOLOGY FOR B2B SYSTEMS

To meet the aforementioned IOBP requirements, we need a methodology that enables a process-based B2B systems development at both business and technological levels, based on a MDA (Model-Driven Architecture) approach (OMG, 2003); (Roser, 2006); (Hammoudi et al., 2010), shifting the focus of software development from writing code to building models. To define a valid separation between business, software and technological platforms in the information systems, MDA uses different kind of models: (1) *Computation Independent Model (CIM);* (2) *Platform Independent Model (PIM)*; (3) *Platform Specific Model (PSM)*. The MDA approach is characterized by a set of vertical transformations/mappings across different phases (PIM to PSM and PSM to Code) using model transformation languages like ATL (Bézivin et al., 2003). The vertical transformation in the downward direction corresponds to process automation approaches where conceptual process models (e.g. BPMN) are transformed to executable processes (e.g. BPEL).

Therefore, in the Figure 2 we depict the proposed a MDA-based methodology which supports: the design of IOBP independent of particular B2B standard; and the automatic generation of each partner's side specifications based on a B2B standard (BPEL) from conceptual IOBP models (UML AD profile).

The main benefits of this methodology are: increase of the abstraction level, since the focus is on the design of technology-independent IOBP; reduction of development costs and time and guarantee of alignment of a business solution with a technological solution, since process executions are generated automatically from process models. The development's methodology is organized into three levels from the abstract conceptual level to the technical execution level: *Collaborative business requirements, Collaborative business process definition, Public processes generation, Internal Private processes generation, and code execution*.

4.1 CIM Layer: Collaborative Business Requirements Phase

The collaborative business requirements phase at CIM level consists in analyzing the problem domain and identifying the business requirements. This is jointly carried out by the enterprises. Hence, it helps the correspondent business analysts to understand

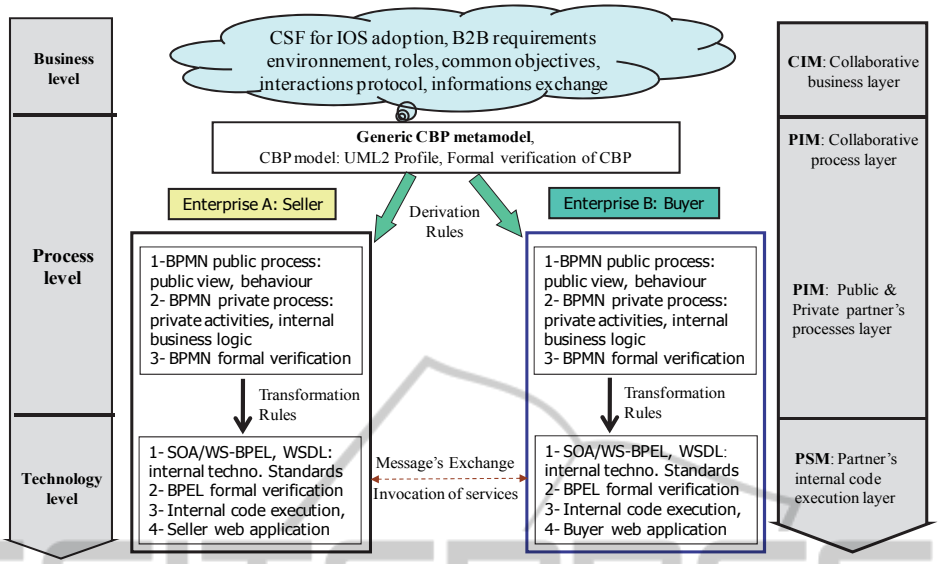

Figure 2: MDA-based methodology for B2B systems development.

the problem. We should capture the process stakeholders (description of various partners and their roles they fulfil) and their communication relationships.

We also define the collaborative agreement parameters and the hierarchy of common business goals to be fulfilled by partners. In this phase we define also the critical success factors for B2B system adoption and use. The collaboration partners are determined by the shared goals of the collaboration and the aspired win-win situation of all partners. The joint aims of the collaboration have to be defined as synthesis of the individual aims.

4.2 PIM Layer: Collaborative Process Definition Phase

The main focus is on the definition of the IOBP, which describe the common behaviour of the interactions between partners from a global viewpoint. The IOBP language was defined as a UML AD Profile in order to provide well-known graphical notations for modelling IOBP. So, the IOBP modelled with UML AD profile instantiate the generic IOBP meta-model proposed for this context. The main contributions of our meta-model are twofold: firstly, we introduce all the IOBP specific concepts in order to model business collaboration; secondly, contribution can be characterized by taking into account explicitly both the four IOBP requirements (autonomy and privacy, decentralization, interaction flows, and technology independence). The use of a UML profile allows us: provide a vocabulary more suitable to model IOBP; add semantics and constraints to the UML meta-model from the modelling domain of IOBP; and reuse existent UML case tools to model IOBP. In addition, this language encourages a top-down approach to model IOBP and provides the conceptual elements to support the modelling of IOBP main aspects:

- Definition of the participants (partners and their collaboration roles) of an IOBP with their communication relationships with description of the hierarchy of common business goals that partners agree on.
- Identification of IOBP required achieving the agreed business goals using the definition of collaborative processes as informal specifications of a set of actions performed by partners.
- Representation of business documents to be exchanged in IOBP with providing the concepts to define the syntactic and semantics structure of business documents.
- Description of the public interfaces of each collaboration role performed by partners. A public business process contains business operations that support the asynchronous message exchange of interactions between partners.

Since IOBP models describe B2B collaboration, it is essential to enable partners to make sure the behaviour of IOBP is well-defined by verifying the structural correctness of a business process. The verification task is concerned to check the process model is free of logical errors (Aalst et al., 2010).

This requires the use of formal verification techniques, which should be applied to detect errors in the integration process models, such as deadlocks, livelocks, etc. With complex real life business processes, ensuring the correctness of the model is a very difficult task, even for a process modelling expert. Therefore, tool support for this kind of analysis would be very important. Hence, we carried out a formal verification of IOBP models, using Petri Nets, starting at an early stage in the development, i.e. previous to the generation of the IT architecture solution.

4.3 PIM Layer: Generation of Public Process Phase

Although IOBP define how partners will coordinate their actions, these processes are not executable. IOBP require the definition of public and private processes each enterprise has to implement for executing collaborative process. A public process or behavioural interface defines the public behaviour of the role an enterprise performs in an IOBP at PIM layer. It defines the public and externally visible behaviour of a partner in terms of the activities that support the receiving and sending of messages with each other. The public process can be derived from the IOBP. To carry out this derivation, we ensure that the semantics of each IOBP element, represented as an UML AD profile, is represented in terms of the elements and semantics provided by BPMN from one partner's viewpoint (e.g. buyer).

4.4 PIM Layer: Definition of Private Process Phase

An internal executable process or orchestration processes is derived from a public process at each partner's side. It adds the private logic of the enterprise required to support the role it perform in an IOBP. The internal business logic includes the activities for producing and processing the exchanged information as well as data transformations and invocations to internal systems. Internal activities, which are required for generating the information to be sent and processing the information to be received from partners, have to be added to the public process to define the corresponding private process. It requires the definition of activity patterns, which capture recurrent business functions to process or generate the information exchanged between partners. At this end, in order to realize the BPMN-to-BPEL transformation, we implement an algorithm inspired from Ouyang et al., (2009), namely BPMN2BPEL. It takes as input a BPD (BPMN Business Process Diagram) represented in XML format and produces the correspondent BPEL code. This step consists of transforming BPMN model obtained from other modelling tool to the corresponding BPMN2BPEL XML input format to bridge this gap.

4.5 PSM Layer: Internal Process and Code Execution Phase

This step deals with the user interface applications development for the "seller" and the "buyer" roles. These partners' user interface applications support the decentralized execution of the IOBP. Although this phase is achieved in parallel for enterprises, they must agree on the B2B standards to be used for implementing the inter-enterprise specifications. Furthermore, on the execution layer these internal processes are used e. g. for the orchestration of Web Services (Peltz, 2003). It consists on the generation of the XML-based specifications of business processes and the B2B systems' interfaces of an enterprise from its platform-specific IT model, which contains the necessary information for the code generation. To this aim, we have implemented a direct connection with the computers and business applications of the buyer organization communicating directly with a seller's web application to send and receive information. After collaborating, both of the two partners' applications progress independently.

5 IMPLEMENTATION OF AN e-PROCUREMENT SYSTEM

To master the complexity of the design and implementation of B2B systems, a tool support is essential. For this purpose, we use an Eclipse-based IDE platform (Eclipse, 2012). By using the Eclipse platform it is possible to guarantee the interoperability of the different plug-ins, tools and transformation languages. In addition, the Eclipse platform enables us to provide an integrated tool that supports the entire development process of the model-driven development methodology for B2B information systems (see Figure 3). Thus, we use the following components:

- A set of Eclipse-based plug-ins, which supports the definition of UML AD profile models as well as BPMN, BPEL and WSDL process models. Figure 3 illustrates the tools used using Eclipse

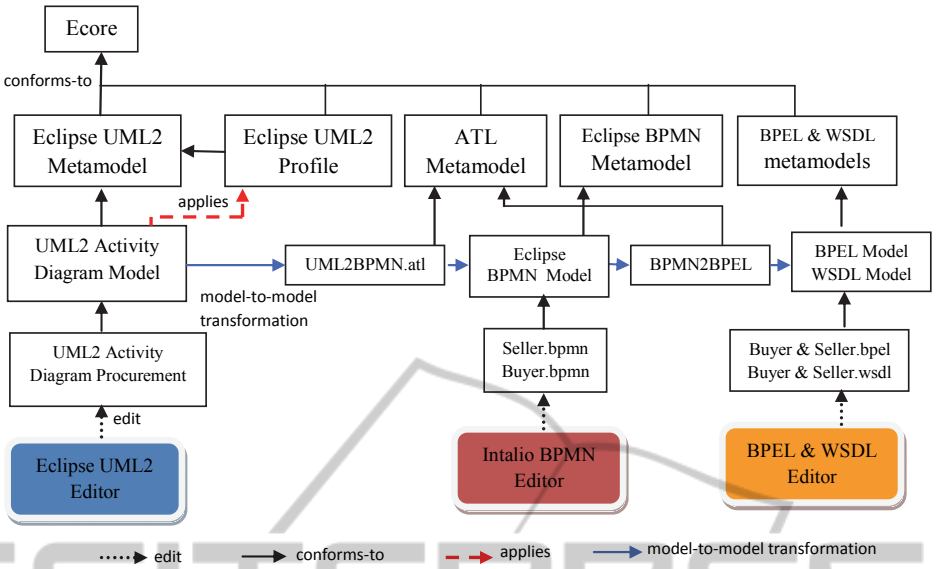

Figure 3: Process model transformations and tools used in the implementation.

UML plug-in.

- An Eclipse-based ATL (Atlas transformation language) tool for model transformations which supports the building of process model transformations (from UML AD profile to BPMN and from BPMN to BPEL). In this way, the derivation of the intra-organizational process "*seller.bpmn*" from the IOBP e-Procurement process, by means of the "*umlProfile2bpmn.atl*" file representing the application of the derivation rules which should be defined before, is carried out with the Eclipse ATL tool.

In addition, we have developed in parallel software tool implementing formal verification techniques which have to be applied to corresponding Petri Nets representation (PNML) (Aalst et al., 2010) of business process. This tool is applied at the three levels (formal verification of UML AD, BPMN and BPEL processes).

In this work, we have developed a prototype e-Procurement system which implements the basic scenario, depicted before by the Figure 1, where a buyer (organization A: the University) makes an online order (purchasing computers, printers, laptops, etc.) to a seller (organization B: Supplier), who processes and fulfils the order through collaborative and internal business processes. Hence, we have implemented an e-Procurement application for each partner's side (buyer and seller) implementing the executable private business processes as web services. Abstract processes described with BPEL provide WSDL interfaces that define the "static interface" of a private process. The interaction that could occur between seller and buyer (see Figure 4) is achieved as a part of the invocation of a web services.

6 CONCLUSIONS

In the frame of this work, we have presented a top-down methodology to build inter-organizational information systems based on MDA approach and rely on the principles of SOA paradigm. Thus, we have proposed a three level methodology for developing B2B systems (*business*, *process* and *technology*). We have proposed an UML AD profile for IOBP modelling. Then, the specific partner's processes are derived based on MDA-based model transformations. Finally the B2B interactions are represented using Web services technology.

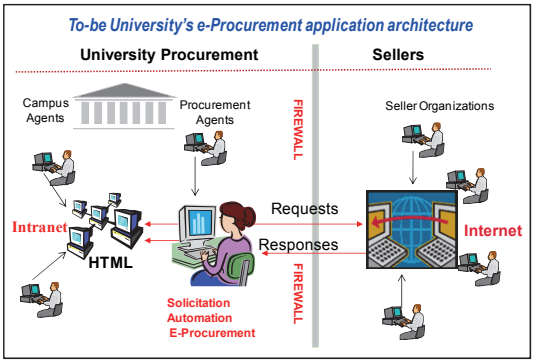

Figure 4: Architecture of the University's e-Procurement application.

There are several open issues to address in the future. Thus, we plan to evaluate our methodology through several case studies in order to verify the completeness of the proposed concepts and artefacts. Another aspect that requires further research is to investigate the explicit support of multi-party interactions (e.g. buyer, seller, and shipper).

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