

# DISTRIBUTED E-BUSINESS ARCHITECTURE FOR SME COMMUNITIES – REQUIREMENTS AND SOLUTIONS FOR REQUEST BASED VIRTUAL ORGANISATIONS

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## ABSTRACT

This paper explores the challenges of constructing a distributed e-business architecture based on the concept of the Request Based Virtual Organisation (RBVO), a B2B value network which is dynamically formed upon demand to meet identified business opportunities. This approach offers significant advantages over the traditional B2B marketplace approach where an intermediate entity dictates particular marketplace policies, provides infrastructure and ensures the virtual presence of the participants in the community. In this paper, we investigate the steps involved in achieving inter-domain end-to-end business collaboration using the structural concepts of the RBVO by presenting a reference architecture and framework (realization of that architecture in a particular class of environments). The practical work was done within the framework of the EU-sponsored LAURA project, which aims to facilitate interregional zones of adaptive electronic commerce using, where applicable, the potential of the ebXML architecture to support the innovative RBVO concept. The LAURA project therefore serves as a case study for the architectural framework presented in this paper.

## KEYWORDS

e-business, business collaboration, ebXML, service-oriented architecture, P2P, distributed

## 1. INTRODUCTION

The original motivation of the research discussed in this paper was to ensure suitability of certain e-business concepts, such as the Virtual Organisation (VO), for SMEs in several regions (UK, Greece, Germany, Bulgaria) and various industry sectors (food, timber, furniture) of Europe. The Virtual Organisation (VO) must be supported by appropriate architectural and technical implementation solutions, as well as suitable operational services, in order to provide its expected value for business partners. In addressing this particular task certain general B2B collaboration aspects were identified which led to the development of a generic architectural framework. Three areas of particular importance were singled out for end-to-end business

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collaboration; discovery and matchmaking of the business partners, secure and reliable business data transmission and business process specification and enactment. These areas, especially the first two, are addressed in greater detail along with the description of practical steps for deriving an e-business service-oriented architecture using the VO concept together with the typical business requirements of SMEs that wish to participate in such arrangements.

The discovery and matchmaking aspect of the overall B2B problem becomes especially important in the SME e-business context, mainly due to the potential for a great number of collaborative participants, the diversity of their capabilities, and the lack of standardisation for product and service description. Traditionally these problems have been addressed using a B2B marketplace approach (Butler Group 2000) where an intermediate entity dictates particular marketplace policies, provides infrastructure and ensures the virtual presence of the participants in the community. The static nature of these virtual formations does not fully address the continuously growing demand to locate products, services and business partners regardless of their physical location and affiliation to an intermediary entity. As a result, the whole set of potential business partners is fragmented into 'islands' and the potential added value of virtual enterprises is not maximized.

In this paper, we consider a specific type of VO, the Request-Based Virtual Organisation (RBVO). A description of the RBVO and its defining characteristics can be found in section 2.2. In order to fully realise the potential of RBVOs as highly dynamic virtual business formations an innovative approach is taken, which is based on natural trading behaviour pattern, expressing direct interaction between partners. Recent developments in the peer-to-peer (P2P) computing field allow this pattern to be implemented. This approach results in a more flexible topology for virtual formations and bridges the gap between the isolated 'islands' thus forming a business to business grid that widens the possibilities for collaboration and increases their availability to business partners.

The further organisation of this paper is as follows: Section 2 serves as an introduction of the concept of VOs and, in particular, of the RBVO, Section 3 introduces the LAURA project as a reference implementation, states the requirements and presents a conceptual solution, and Section 4 outlines architecture requirements and technology needs of the solution, introduces a realization framework and presents the key design decisions. Finally, Section 5 concludes with a summary of the overall effort and outlines future research.

## **2. REQUEST BASED VIRTUAL ORGANISATIONS**

### **2.1 The Basic Concepts of Virtual Organisations**

The discussion of virtual organisations in the literature lacks consistent terminology, with terms such as virtual networks, dynamic networks, and extended networks often being used as interchangeable synonyms, and also to indicate different characteristics related to longevity, purpose, and culture. (Aldrich 1999, Bovet and Martha 2000, Davidow and Malone 1992, Jarillo 1993). However, the commonality between each of these terms lies in the blurring of traditional external organisational boundaries, often with e-commerce as a key enabler. The separation between internal and external processes becomes less clear as inter-organisational systems facilitate more coordinated exchange and sharing of information.

A virtual organisation has a high degree of interdependence between the participant organisations, and its success will depend as much on the reliability of the participants as on the reliability of the technology. The 'virtualisation' of companies to form an extended enterprise also means that if one partner improvises and fails a process execution, then the whole network may break down because all partners are taking part in the same overall logical business process. A survey carried out by Tung et al (2001), for example, found that businesses are more concerned that their business partners provide assurances that commitments will be kept, and that keeping commitments is the most important dimension of trust influencing participation in B2B e-commerce in general. The supporting e-commerce architecture will determine the manner in which VO structures can evolve. The more flexible and adaptable the technologies are, the more capable they are to support the full VO lifecycle. This may involve the innovative use of e-commerce technologies for new

organisational arrangements, value acceleration and new value added processes. Low cost and ease of use of the enabling technologies are key issues for SMEs participating in VOs.

According to Strader (1998), the life cycle of a VO can be divided in four distinct periods:

- **Identification:** At this stage, the identification of potential market opportunities and communication to all organisations takes place. Of course, each organisation has the ability to identify opportunities itself.
- **Formation:** After the opportunity selection, an agreement is made about which organisations will participate and the role assignment is conducted.
- **Operation:** At this stage, all participants work towards a common target.
- **Termination:** At this stage, a report is composed. Asset dispersal takes place.

## 2.2 Request Based Virtual Organisations

The Request-Based Virtual Organisation (RBVO) (Svirskas and Roberts 2003) is a specific type of VO in which a cluster of partnering organisations that have totally replaced their vertical integration into a virtual one. The lifecycle of the RBVO remains the same as that of the 'classic' VO, however there are a number of key areas in which the RBVO differentiates itself:

- A possibility for an enterprise to discover potential business partners upon demand and advertise itself in a standard way.
- Short-lived ad-hoc virtual formations of collaborating partners.
- Highly dynamic involvement of an enterprise in different e-business activities, serving different roles (those defined and advertised) at the same time, if needed.

These characteristics of a RBVO largely contribute to the agility dimension of a VO. The term RBVO may be considered broadly analogous with the concept of the agile enterprise, or to be more precise the virtual agile enterprise. Meade and Rogers (1997) define an agile enterprise as an enterprise whose processes are designed specifically to respond effectively to unanticipated change. Preiss (1995) summarises four dimensions of an agile enterprise concerned with cooperating to enhance competitiveness, customer service, managing change and uncertainty, and leveraging the impact of people and information.

## 3. A REFERENCE IMPLEMENTATION

The authors of this paper are currently involved in a European Commission project sponsored by The Information Society Technologies (IST) Programme that is part of the Fifth Framework Programme for Research, Technological Development and Demonstration Activities. The project, called LAURA - 'Adaptive Zones for Interregional Electronic Commerce based on the concepts of Request-Based VO and sector-specific Service Level Agreements' (LAURA 2002) is directly related to the issues of bringing e-business to SMEs. LAURA is a project that innovates in terms of focusing on RBVOs as a specific type of the VO taxonomy. The LAURA project intends to exploit the RBVO concept to facilitate in particular cooperation among SMEs to enhance the competitiveness dimension of enterprise agility.

The proposed e-business environment consists of the two main parts: a business service infrastructure and e-business software system, which supports the infrastructure. In this section we will outline the business requirements for such a solution, later we will examine architectural and technical challenges arising as a result of the business requirements.

### 3.1 The Business Requirements and Main Implementation Challenges

Firstly, the solution should be simple and easy to use for a business user. Simplicity is a crucial factor when attracting SMEs without previous e-business experience. EU Reporter (2003), an independent business

newspaper, wrote "the most important thing for SMEs, if we want them to be properly integrated, is that businesses have information and communication technology (ICT) in the same way everyone has a phone in their home". In order that this ambitious goal can be realised, both availability and reliability aspects of the service must also be carefully considered.

Secondly, the solution should address the most common needs of SMEs. According to a survey, conducted by the LAURA consortium in different regions of Europe (Greece, Bulgaria, and Germany), most of the SMEs would like to increase their sales, customer base and reach for the new markets as a result of e-business practice adoption. Increase of the supplier base is considered a little less important, but still a strong driver (LAURA 2003).

Thirdly, the solution must capture the common needs typical for such e-business formations of SMEs and develop a reusable framework, which can be used as a reference when building similar solutions. Certain SME-specific collaboration patterns should be distinctively captured and supported by business and technology solutions.

Therefore, the primary goals of the proposed service are associated with providing a means:

- For potential business partners to advertise their own products and services
- For buyers to advertise purchasing needs for potential sellers to find them
- For buyers to search for both the products offered on sale and for the parties potentially interested in seller's products:
  - "Who sells PC main boards, processors and coolers for a bargain price?"
  - "Who wants to buy PC main boards bundled with the CPUs, pre-tested and in volumes?"
- To reach across the boundary of the "home domain" when looking for a business partner
- A way to conduct trusted, secure and traceable business collaboration sessions with the chosen partners
- To be in touch with a local structure, which could encourage and help to use the potential of e-business

### 3.2 LAURA Conceptual Framework

Figure 1 presents the conceptual model of the LAURA project from the structural and life-cycle perspectives.

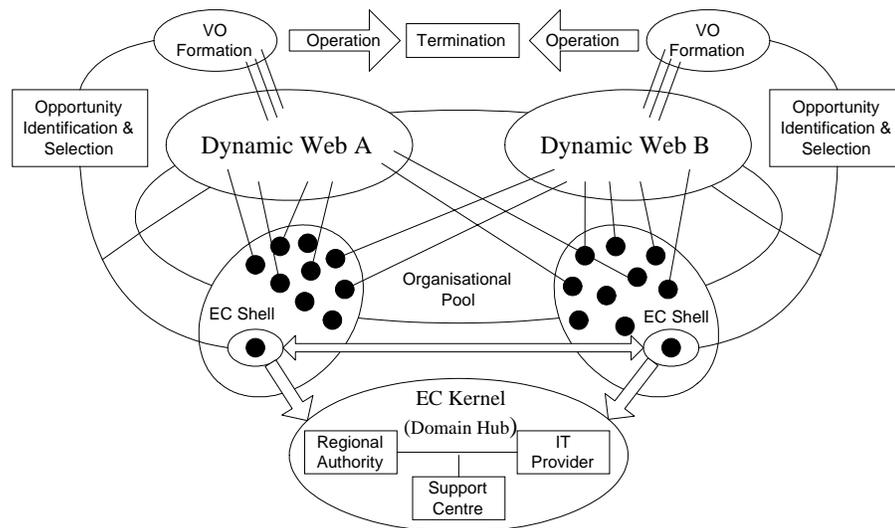


Figure 1. The LAURA Conceptual framework (adapted from Svirskas and Roberts (2003))

The model builds on the lifecycle and structural concepts of VO and introduces a business context dimension, aligned with the business needs and other requirements of SMEs. The following concepts distinguish the LAURA conceptual model:

- *LAURA E-Commerce (EC) Shell (domain)* is a set of SMEs belonging to a certain geographical region and registered with the LAURA network via a LAURA support centre. The notion of domain and presence of multiple domains in LAURA network allows us to refer to the architecture as *distributed*. The LAURA domain hubs and the SMEs using LAURA are together referred to as LAURA peers.
- *LAURA EC Kernel* is the focal point of an EC Shell. The main component of the kernel is the support centre, which is responsible for provisioning of both commercial and IT (outsourced to the IT provider, if needed) services to the SMEs. The role and added value of EC kernels is to promote and facilitate e-business services among the local SMEs, mainly through the support centres. The support centre hosts the necessary software, which allows SMEs to register themselves with the support centre, manage product catalogues and conduct their business. The software is accessible by SMEs using a browser interface and, when inter-regional services are necessary, it also supports communication with other EC kernels on behalf of its EC shell members.
- *LAURA Network* is an inter-domain collaboration infrastructure, which defines a set of rules and provides arrangements for inter-regional (inter-domain) business collaboration between the SMEs. The LAURA effort aims to further enhance the VO benefits to SMEs through proactive regional support services. LAURA support centres aim to shield the SMEs from the technical complexities of e-business interactions, increase trust of the network by screening the SMEs joining it and facilitate formation of VOs by providing SMEs with assistance to identify potential business partners, thus addressing some of the trust, knowledge and IT issues which might inhibit the formation of VOs.

## 4. RBVO SUPPORTING ARCHITECTURE

There are many important aspects to consider when constructing solution architecture, however we will touch those most relevant to the nature of the RBVO concept, namely services available to the participant organisations and their invocation principles. Some user requirements are now discussed in order to demonstrate the connection between them and the more formal business collaboration modelling, specification and realization approach. The most significant user requirements among those related to the basic VO lifecycle are:

- Discovery of desired products
- Discovery of potential business partner
- Conducting of business conversation between the partners

The architecture of the discussed solution must cope with the somewhat ambitious goals outlined above while also satisfying a set of specific requirements, dictated by the model itself and the application domain. Firstly, we will outline the basic architectural principles that define the LAURA solution, and secondly we will cover elicitation aspects of architectural requirements and the requirements themselves and finally the main realization decisions will be presented. This contributes to one of the goals of the paper - to present reference architecture (a set of rules defining component interactions) and a framework (realization of that architecture in a particular class of environments) to demonstrate our findings. The meanings of *reference architecture* and *framework* used here are borrowed from Filman (1998).

### 4.1 Service Oriented Architecture

One of the possible ways to model an RBVO is to consider it as composed of a collection of interacting *services*, with each service providing an interface to a well-defined functionality. Brown (2003) defines a service as follows: 'A service is generally implemented as a course-grained, discoverable software entity that

exists as a single instance and interacts with applications and other services through a loosely coupled (often asynchronous), message-based communication model'. The system as a whole is designed and implemented as a set of interactions among these services. This approach fits the "request on demand" concept, which is an integral aspect of the RBVO.

Exposing functionality as services allows other pieces of functionality (perhaps themselves implemented as services) to make use of them in a natural way regardless of their physical location. A system evolves through the addition of new services. The resulting Service Oriented Architecture (SOA), first described in 1996 by Gartner. Inc. (Gartner 2003) defines the services of which the system is composed, describes the interactions that occur among the services to realize certain behaviour, and maps the services into one or more implementations in specific technologies (Brown 2003).

The SOA approach is the latest in a long series of attempts in software engineering that try to foster the reuse of software components (Leymann et al. 2002). According to Ferguson et al. (2003), SOA differs from Object Oriented (OO) and procedural systems in one key aspect, binding. Services interact based on what functions they provide and how they deliver them, whereas OO and procedural systems link elements together based on type or name. SOA also assumes that things can and will go wrong in a distributed heterogeneous environment – lost messages, crashing services, malicious invocation attempts and so on, therefore assumptions about presence of different errors is made explicit.

## 4.2 LAURA Realisation Framework

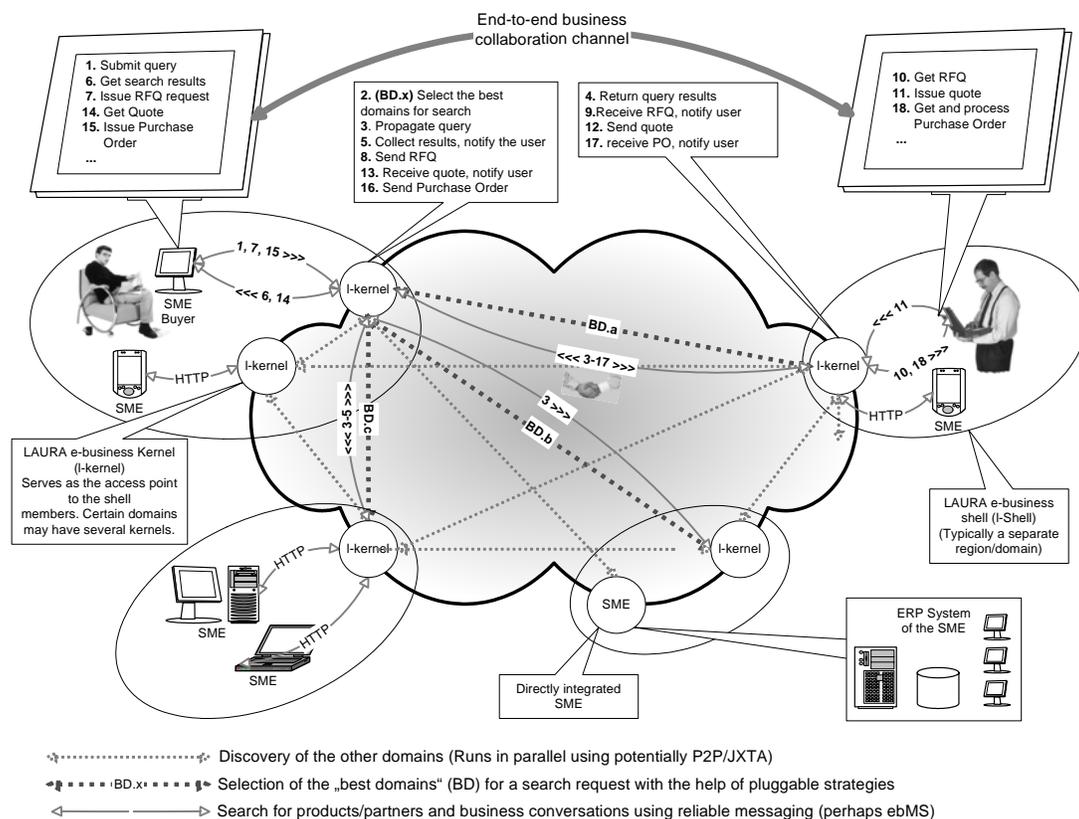


Figure 2. The LAURA realization framework

The ultimate goal of the solution is end-to-end collaboration between business partners, as indicated by the business and user requirements. This section discusses the architectural constraints required for reliable end-to-end business collaboration, and outlines the main ideas for use case realisation. Due to the multi-domain nature of the LAURA network, end-to-end business collaboration is a multi-step activity, involving SMEs and their corresponding support centres which broker the collaboration. Figure 2 is a high level view of the LAURA realisation framework, illustrating the steps involved in inter-domain end-to-end business collaboration. These detailed steps indicate the functionality required to support the first three phases of the VO lifecycle – identification, formation and the initial operation phase.

Due to the requirement by SMEs for simple, accessible business technologies, interaction between the end-user and the LAURA network occurs over a WWW interface using HTTP(S) protocol. An in-depth discussion of this realisation framework is outside the scope of this paper, and we focus here on the principle architectural decisions supporting the RBVO concept. This realisation has been performed at a high level in order to better illustrate the basis of the architectural decisions made, and to avoid being overwhelmed with specific technical information. The proposed realisation scheme captures commonalities of SME B2B e-business, and therefore the conceptual and architectural decisions can be applied to this class of solutions.

#### **4.2.1 Identification**

The identification of potential market opportunities takes place over steps 1 to 6 in figure 2, which have been designed to ensure efficient propagation of the search requests and delivery of the results to the requester. In the LAURA solution, we have used an open source e-business component framework developed by the Open For Business Project (OFBiz, 2003) which provides the basic functionality such as catalogue management, user registration, business transaction monitoring, and reporting. Roberts et al (2003) elaborate on OFBiz usage for the LAURA project. Each organisation has the opportunity to advertise itself in a standardised way, and each has the ability to identify market opportunities.

The solution proposed is a multi-domain system, and for each support centre hub the first step performed is the discovery of other support centres (domains). Discovery of the remote domains by a domain hub is encapsulated into a generic interface, which allows different discovery techniques, one of which is based on emerging Peer-to-Peer (P2P) technology and a Java implementation in particular – JXTA (JXTA 2003). Domain hubs use JXTA to exchange their meta-data and build lists of remote domains for subsequent product search. Each domain hub maintains a ‘neighbour domain directory’ which contains the attributes of other domains and the hubs servicing them. It is necessary to keep the list as accurate as possible by regularly checking availability of the domains (their hubs) and possibly maintaining a “ping-time” parameter for a domain to estimate its “proximity”.

Domain hubs perform search of products and partners on behalf of SMEs by propagating the queries to selected remote domains. The subset of domains to which the search query is forwarded is selected so as to optimise the search process in terms of speed and relevance of the results returned. The service should intelligently choose the domains on behalf of the user, and the choice should be made based on:

- Explicit user business preferences (e.g. a wish to do business in a specific geographical region, a specific product or type of service)
- Explicit user service preferences (e.g. number of business options to choose from, speed, etc.)
- Indirect user business preferences (e.g. a wish for certain goods of good quality and with fast delivery)
- Accumulated meta-data of business domains, available at the time of choice (e.g. business sector involvement, number of consumers and suppliers per sector, etc.)
- Accumulated historical data about business transactions conducted in the past (business sectors, percentage of completed transactions, amounts, customer retention rate, etc.)
- Explicit business practice related feedback provided by the business partners about mutual business experience (e.g. quality of service, ease of communication, trustworthiness, etc.)

#### **4.2.2 Formation, Operation and Termination**

Step 7 and onwards in figure 2 illustrate the start of the formation and operation processes in the RBVO lifecycle. The technologies required to support the formation, operation and termination phases are very much the same, since these phases represent points in the execution of the same business process. At the

formation of the RBVO, the participants are decided upon, and the role assignment is conducted. The requirements on each partner are made explicit by the specification of an ebXML business process. The transport chosen for this task and subsequent business conversations is ebXML messaging (ebXML 2003). The simplicity and flexibility of the formation process provides the ability to create short-lived virtual organisations of collaborating partners. This allows highly dynamic involvement of an enterprise in different e-business activities, serving different roles (those defined and advertised) at the same time, if needed. These are the key features of the RBVO.

Business processes specify the choreography of business transactions in collaborations between the partners and these are modelled and specified using ebXML BPSS (ebXML 2003). Each business process is essentially an exchange of business documents, and we have chosen to use the Open Applications Group Integration Specification (OAGIS) (Rowell 2002, Flebowitz 2003) document collection, since it provides the most comprehensive selection of business documents currently available.

For each of the formation, operation and termination phases of the lifecycle, business conversations are brokered by the domain hubs on behalf of the SMEs. The inter-domain infrastructure should support secure and reliable business collaboration according to the business scenario rules. This is a much more challenging task than support of 'local' business collaboration when the business partners virtually 'reside' in the same domain. The most important issues here are:

- Secure and reliable messaging over the Internet
- Business documents specification, applicable standards
- Business process decomposition, identification of reusable collaboration scenarios
- Machine-readable business process definition and their run-time interpretation
- Atomicity of business transactions

As previously mentioned, trust is perhaps the most important issue in attracting SMEs into e-business. Security and identity management is a more complex problem in a fragmented and multi-domain environment. This aspect needs to be addressed properly at architectural and infrastructure level in addition to the notion of "trusted business community based on locally verified information", which is aimed to help business networks of this type to be more attractive for security-concerned users. At the termination phase of a transaction, reports are maintained on the performance and contributions made by each of the partners involved. This information can then be used to determine the reliability of a participating SME based on their previous transaction history.

## **5. CONCLUSIONS AND FUTURE RESEARCH**

Clusters of SMEs operating as a RBVO can be enabled by a pragmatic choice of architectures and frameworks to support SME B2B transactions. However, there are practical considerations that need to be made in terms of the relationship between the conceptual models of virtual organisations and their implementations. A distributed e-business architecture solution suitable for SMEs has been designed in the framework of the LAURA project. The project aims to bring together the best practices and standards of e-business with local business knowledge and feedback from the field in order to create an efficient and trusted e-business environment for SMEs. The paper also positions the architectural options of SME-oriented e-business solutions in the context of the choices made by the LAURA project team i.e. an Open Source based e-business framework as the functional foundation and the ebXML framework as the collaboration vehicle, where appropriate.

One of the main results of the paper is the introduction of a reference framework which could serve as a basis for the implementation of similar B2B solutions. The presented framework is based on the principle of a Service Oriented Architecture, and it provides a modular set of services that together form the LAURA Business Collaboration Service. This Business Collaboration Service can be embedded into various environments, such as LAURA domain hubs or the B2B software systems of advanced SMEs. The framework establishes a collaboration model based on two-step matchmaking of the business partners. Firstly, the most likely candidates are selected from all the available peers using metadata and historical business transaction data, and secondly the search for products and services is propagated to the selected

peers to continue the matchmaking procedure. Furthermore, discovery of the peers is encapsulated into a generic interface, which allows different discovery techniques, based on Peer-to-Peer (P2P) technology and a Java implementation (JXTA). This implementation based on a P2P approach provides a means of aligning the structure of the IT architecture to the flexible and loosely federated structure of an RBVO.

As part of the LAURA project a prototype e-business system for participating SMEs in the selected regions is being undertaken with a view to gauging the viability of using such a system to support collaboration for RBVOs through full regional and inter-regional implementations. It is expected that the results of this investigation will help illustrate the strengths and weaknesses of the solution, and provide direction for future research.

Some of the ideas and experience gained in the LAURA project will be applied in another EU sponsored project related to dynamic VOs – TrustCoM (Dimitrakos 2004), as one of the authors joins the TrustCoM project team. The main objective of TrustCoM is to provide a trust and contract management framework enabling the definition and secure enactment of collaborative business processes within Virtual Organisations that are formed on-demand, are self-managed and evolve dynamically, sharing computation, data, information and knowledge across enterprise boundaries, in order to tackle collaborative projects that their participants could not undertake individually, or collectively offer services to customers that could not be provided by the individual enterprises.

A novel trust and contract management reference architecture that will enable collaborative work within VOs leveraging the emerging convergence of Web Services and Grid technologies will be constructed. A realisation of the TrustCoM framework will be delivered by means of open-standards Web Services based specifications and a reference implementation. Validation will take place within industrial strength test-beds in the areas of collaborative engineering and provision of ad hoc, aggregate electronic services. The project also aims to produce a set of Web Services profiles, that bring together and potentially extend selected Web/Grid Services specifications at specific version levels, along with conventions about how they work together to support potential implementations of the TrustCoM framework. Despite the differences of technologies used in the two projects, the set of issues is largely the same in both cases – location of the partners and services, selection of the appropriate services, secure collaboration, business rules enactment, etc. This similarity helps to transfer the knowledge and apply it in a new context.

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