47 THE ECOLEAD ICT INFRASTRUCTURE FOR COLLABORATIVE NETWORKED ORGANIZATIONS

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This paper presents a distributed and open ICT infrastructure that is being developed in the ECOLEAD IST IP project to help members of Collaborative Networks in doing businesses and collaborations more efficiently. ICT-I design relies on the service oriented architecture paradigm, and it is implemented with web-services. ICT-I services are to be used on demand and pay-per-use models. It is flexible to support an easy entrance of new services and the withdrawn of others. So far the type of organizations envisaged by the proposed ICT-I are the ones members of virtual breeding environments, virtual organizations and professional virtual communities. This paper details the ICT-I requirements, its architecture and services. A small description of a first ICT-I prototype is given in the end.

1. INTRODUCTION

Reinforcing the effectiveness of collaborative networks and creating the necessary conditions for making them an endogenous reality in the industrial landscape, mostly based on SMEs, is a key survival factor. Collaborative Networked Organizations (CNOs) has been considered the discipline in charge of studying all the manifestations of organizations when they work in an inter-linked and organized way (Camarinha-Matos et al., 2004a). One of these manifestations is Virtual Organization (VO). A VO is a dynamic, temporary and logical aggregation of autonomous organizations that cooperate with each other as a strategic answer to attend a given business opportunity or to cope with a specific need, and whose operation is achieved by a coordinated sharing of skills, resources and information, totally enabled by computer networks (Rabelo et al., 2004).

The implantation of any form of collaborative network depends on the existence of an ICT infrastructure/middleware that allows different distributed/heterogeneous applications/actors to communicate with other transparently and seamlessly.

The fast evolution of ICT technologies with reduced life cycles and the need to cope with technologies with different life cycles and at different stages of the corresponding life cycle have represented a major difficulty for developing advanced collaborative tools. Therefore, in order to leverage the potential benefits of collaborative networks, more flexible and generic infrastructures need to be designed and implemented enabling networked organizations to agilely define and set-up relations with other organizations (Camarinha-Matos et al., 2004b).

Please use the following format when citing this chapter:

Rabelo, R. J., Gusmeroli, S., Arana, C., Nagellen, T., 2006, in IFIP International Federation for Information Processing, Volume 224, Network-Centric Collaboration and Supporting Fireworks, eds. Camarinha-Matos, L., Afsarmanesh, H., Ollus, M., (Boston: Springer), pp. 451–460.

This paper presents the ongoing work for developing an ICT infrastructure (*ICT-I*) that deals with such requirements. It is being developed within the ECOLEAD Project (www.ecolead.org), which aims to create strong foundations and mechanisms needed to establish the most advanced collaborative and network-based industry society in Europe.

The paper is organized as follows: Section 2 stresses the requirements of an ICT-I for CNOs. Section 3 introduces the proposed ICT-I rationale and architecture. Section 4 depicts the ICT-I services. Section 5 gives an overview of a first implementation. Section 6 provides preliminary conclusions and future steps.

2. REQUIREMENTS OF AN ICT-I FOR CNO

When dealing with ICT infrastructures for CNOs it is also important to consider the different nature and size of the companies. In Europe, more than 98% of the companies are SMEs (Europe-EU, 05). As such, most of them have difficulties to have access to the main products of the market as they are very complex, costly and requires a high investment on software and hardware (and people to maintain this). Actually, available solutions and business frameworks offer some support for collaboration. They support quite well traditional business processes transactions (purchasing, selling, manufacturing, shipping, etc.) and their integration at the intra-organizational level. More recently they have been also investing on the support of these transactions at inter-organizational level. These transactions represent means to support effective collaboration, i.e. they can be seen as collaborative services.

However, the kind of collaboration required by CNOs is rather different. In the envisaged scenario of the ECOLEAD project, primary sources of requirements are *VBE – Virtual Organizational Breeding Environment* (Afsarmanesh et al., 2005), *VOM – Virtual Organization Management* (Karvonen et al., 2005) and *PVC – Professional Virtual Communities* (Bifulco et al, 2005) types of CNOs. Roughly, this means the need for building an ICT infrastructure that allows well established groups of enterprises and of professionals to collaborate between each other as well as to manage this collaboration. Each of these areas has different needs, dependent on the nature of a CNO and of its actors. For example, both VBEs and PVCs need: ways to exchange information between their members in a secure way; services for VO creation support (e.g. partners search and selection, negotiation); CSCW tools to augment the efficiency of a collaboration as well as to manage involved IPR; means to monitor and to assist decisions upon current VOs; information historical should be generated and managed; business processes should be modeled and further supervised; among many other needs. These requirements cover part of the problem and can be seen as "vertical" and specific requirements.

Other requirements are technological, i.e. more "horizontal", independent on the nature of a CNO and of its actors. Some relevant requirements are: open, scalar and technology-independent infrastructure; federated information and resources management; flexible control mechanisms supporting a large variety of behaviors; full e-transaction security; privacy guarantee; and infrastructure reliability.

There are many B2B frameworks and collaborative platforms developed as products and in research projects that could be used to support those collaborative requirements. However, they present several relevant restrictions for their fast and

easy adoption by (CNOs of) professionals and SMEs. Most of them, at several and variable levels, are not open at all, are not free, requires huge infrastructures, are very expensive and complex to deploy and difficult to use, and they don't support at all the CNO requirements. That is the niche ECOLEAD ICT-I intends to embrace. Actually, it doesn't aim to compete with existing platforms. Instead, some of them will be used to support specific issues (e.g. fault tolerance, services persistence), some of them will be complemented and/or adapted to ICT-I needs (e.g. CSCW and ontology tools) and there are issues for which specific CNO-related solutions will be developed. Therefore, ECOLEAD ICT-I will act as a comprehensive, integrated, seamless and transparent platform to better support CNO needs.

3. PROPOSED ICT-I

ECOLEAD ICT-I intends to cover part of this gap based on the vision of a *plug & play* infrastructure. This means that any VBE/VO/PVC member will be provided with adequate tools to be easily *plugged* into the ICT-I / CNO community and to *play* (i.e. to collaborate with other organizations) in secure, on-demand and pay-per-use way. In resume, ICT-I enables people to collaborate, systems to interoperate, knowledge to be shared, and processes to be synchronized. The authors advocate that, as such, ICT-I represents a step towards reaching the requirements of the *service oriented economy* of the future and *sustainable business networks*[1].

In order to cope with this need, ECOLEAD ICT-I has been fully developed based on open platform-independent specifications and ICT standards.

There is a number of conceptual approaches that can be applied to support these features. ICT-I applies the SOA (*Service-Oriented Architecture*) approach. SOA can be generally defined as an architectural paradigm for components of a system and interactions or patterns between them (Singh et al., 05). In other words, it can be seen as an application architecture in which all functions – or *services* – are defined using a description language and have invocable interfaces that are called to perform business processes. A service is seen as a software element that can both call for another service and be called by another service or, in other terms, a software system designed to support interoperable machine-to-machine interaction over a network (www.w3C.org). A service has an interface described in a machine-processable format that is usually platform-independent, meaning that a client from any device using any operating system in any language can use the service.

Web-services (WS) is the core technology that has been used to implement the SOA approach in the ECOLEAD ICT-I.

An important feature for the desired flexibility and scalability is that ICT-I is not a monolithic piece of software that follows the traditional notion of middleware as a "close world bus" that allows integration of distributed / heterogeneous parts. Instead, ICT-I is seen as a "pulverized" open bus composed of many distributed services. That is why it has been called ICT *infrastructure* and not ICT *middleware.*

3.1 Services Federation

A *Federation* corresponds to groups of devices and software components into a single, dynamic distributed system. The resulting federation provides the simplicity of access, ease of administration, and support for sharing that are provided by a large monolithic system while retaining the flexibility, uniform response, and control

provided by a personal computer or workstation. Members of the federation are assumed to agree on basic notions of trust, administration, identification, and policy. The dynamic nature of a federation of services enables services to be added or withdrawn from a federation at any time according to demand, need, or the changing requirements of the workgroup using it (Sun, 99).

Adapting this concept to the envisaged ICT-I environment means to see all the involved services as members of a community, the *Services Federation*. This federation comprises the set of distributed services related to: i) the own ICT-I lifecycle and to the supporting services for high-level applications; ii) the CNO life cycle (comprising VBE, PVC and VOM vertical services); and iii) legacy / (intra-organization) systems services. The goal is that all existing services can coexist in a virtual logical repository of services and that can be accessed transparently and seamlessly according to some rules. From the ICT-I point view, the users and applications do not need to know about which services are needed to support a collaborative transaction, where they are, how they should be executed, and which technologies have been used in their implementations. Services are invoked, searched, discovered and properly executed no matter where they are.

One of the ICT-I underlying goals is to act as a catalyzer of independent software providers that can provide their services through the ICT-I. Such community can therefore be seen as a "CNO of services providers", which in turn has to establish its own policies and rules.

3.2 ICT-I Scope

The use of the ICT-I can be illustrated in Figure 1. Each CNO organization/actor tends to have its own portal. Each portal represents the access to services that have user interfaces. Depending on the configuration done, wider integrated collaborative portals can be created. The services themselves are stored in distributed services repositories, forming the Services Federation. From a user-centric perspective, CNO actors can, under flexible but well defined security and on-demand usage policy models, communicate (*C*), access data and information repositories (*D*), search and retrieve distributed bodies of knowledge as well as ontologies (*K*), and monitor and control the execution of business processes among CNOs (*P*).

From another side, networked organizations have their legacy systems. They perform their business transactions making use of ERP systems / B2B platforms, generating information to corporate databases. In general, ICT-I assumes that this information can be accessed by enterprise's services that somehow wrap existing legacy functions as well as that ICT-I services can also be invoked from enterprises' environments. This extends the level of collaboration as all (wrapped) enterprises' services can be accessible by other enterprises, according to security configurations.

As stressed in section 4, ICT-I is composed of Horizontal (*C K P D*) and Basic services. In practice, its services can be invoked in three basic situations: *(a)* Client-Server, *(b)* Intra-Server, and *(c)* Server-Server. Diverse ICT-I services (see section 4) can be invoked in each of these three situations. *Client-Server* case is used when a CNO actor (e.g. a VBE member) wants to access services provided by other CNOs through a centralized portal server. For instance a VO Planner who wants to know the competencies of VBE members or to open collaboration sessions with human peers in the CNOs. In this case, ICT-I needs to support the security and messaging, for instance. *Intra-Server* is used whenever a CNO portal is designed under SOA

concepts, aggregating several vertical services. Depending on the business rules that have driven the services' logic, ICT-I can support, for instance, the orchestration of the required services. *Server-Server* is used to support inter-CNO collaboration. For example, when a PVC portal needs to access a VBE for obtaining the list of companies that has some profile. In this situation semantic mediation service for dealing with the different ontologies can be used.

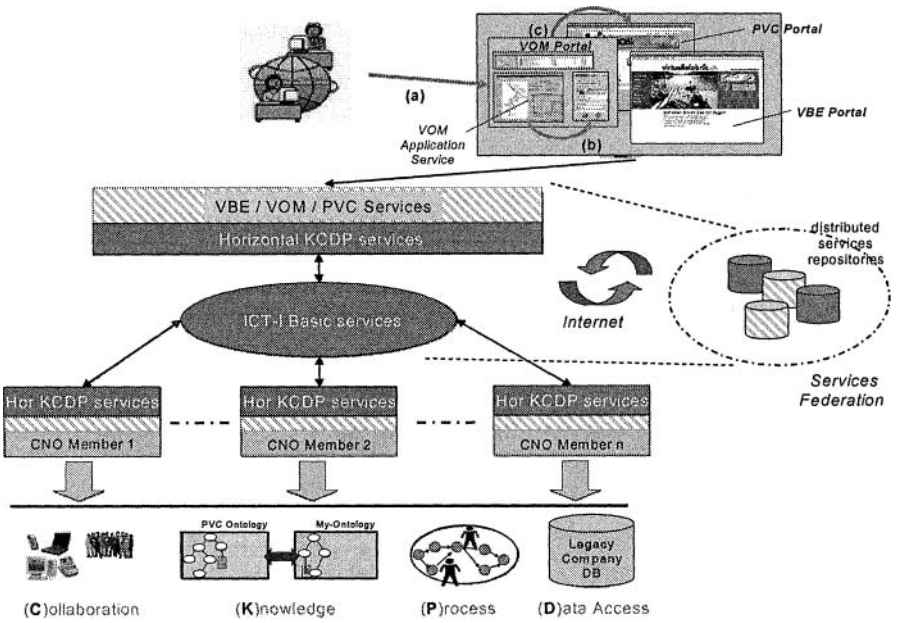

Figure 1 – Example of a scenario for the use of ICT-I

3.3 Interoperability and Security

Interoperability and security play an essential role in any infrastructure where CNO actors are distributed and heterogeneous. These two issues are covered in this paper in a very shallow way as it intends to focus on the ICT-I architecture. Detailed information about the ICT-I approach and strategy for interoperability and security can be found in (Arana et al., 2005) and (Sowa et al., 2006), respectively.

Interoperability is not the focus of the ECOLEAD ICT-I. It is seen as an *enabler* for collaboration. In this sense, attention has been put only on the essential aspects of interoperation required to support the planned collaborative services, also benefiting from outcomes of other initiatives in the area. The interoperability scope comprises the cases (a), (b) and (c) mentioned in the previous section.

Security in CNO is fundamental as a way to reinforce trust building. The security framework that is being incorporated in the ICT-I supports authentication, authorization and accounting along the collaborative transactions that are carried out among CNO partners, regarding the different roles and privileges each one has in a CNO. This framework is flexible, allowing responsibilities (and eventually delegations) to be dynamically assigned to actors and required security mechanisms settled accordingly. It means that the access to the services of the federation is filtered considering the CNO actors' privileges, as illustrated in figure 2.

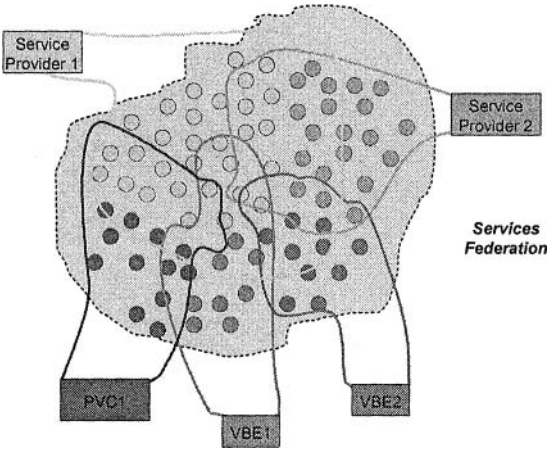

Figure 2 - Local Service Registries / Services Visibility

3.4 ASP Model

Considering the essential natural of CNO members (which uses to have significant financial and human resources restrictions to buy and to maintain sophisticated and huge infrastructures), their natural geographic distribution and mobility issues, ASP (*Application Service Provider*) model (Dewire, 2002) seems the most adequate for the ICT-I. This means that ICT-I services are accessed remotely, on demand, paid-per-use, based on a contractual software-based service for hosting, managing and providing access to the services federation, no matter where the (distributed) repositories of services are. This gives rise to several business models to exploit ICT-I, as stressed in (Borst et al., 2005), making possible to offer an affordable and "made to fit" ICT-I for companies.

3.5 ICT-I Reference Architecture

In order to provide an open and scalar model, ICT-I has a reference architecture from which instances-of it can be derived for different CNOs. Figure 3 presents the wider view of the ICT-I Reference Architecture. Its basic rationale is given below, and its services are generally explained in Section 4.

VBE, VOM and PVC have some very specific needs for each one. Thus, it can be said that they have *vertical* needs/services. As they have some common needs to help in the execution of their services, ICT-I provides *horizontal* services for them, i.e. services independent of any of those three specific application sub domains.

Horizontal services need in turn lower-level services to support their execution, transparently to the application services / CNO actor. These services are then seen as *basic* services. They are domain-independent and are basically used by other services. Basic services represent the very core of the ICT-I, comprising the discovery, selection and orchestration of services, security, basic interoperability services, etc.. They are called *Platform Independent Basic Services* (PIBS). The services intrinsically dependent on the PIBS's implementation are called *Platform Specific Basic Services* (PSBS).

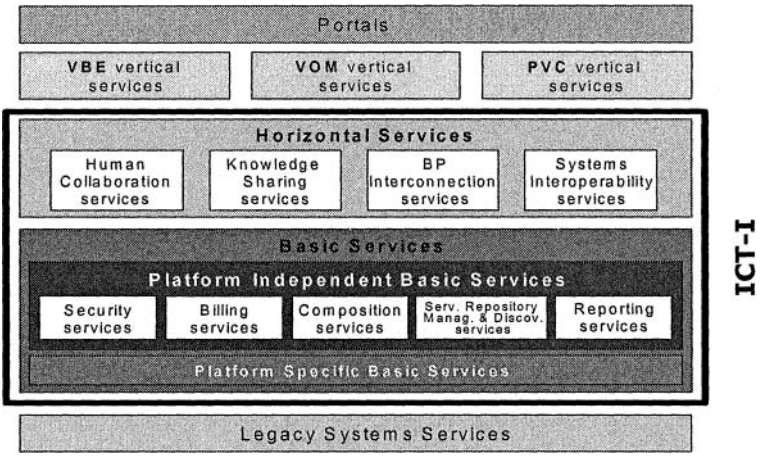

Figure 3 – ICT-I Reference Architecture

There are *legacy systems* services, which essentially provide information about activities inside a given company to satisfy vertical services needs. They use to be implemented in heterogeneous platforms and native front-ends.

Therefore, seen as a whole, vertical, horizontal, basic and legacy services compose the Services Federation.

A special and optional element of this architecture is *portals*. They act as an integrator front-end to the services themselves or even to other portals as a way to invoke services directly by the end-user. Portals are not seen as services.

Per definition, there is not a hierarchy among services. For example, the execution of vertical services requires the combination of services of different nature (considering security aspects, levels of visibility, context awareness, etc.) no matter the services type and layers they are placed. Anyway, the set of services to be involved and the sequence of their invocation / execution are configured by means of an orchestration / composition service.

Although not shown in the figure, there is another "class" of services called ICT-I management services. They are fundamentally used to manage the ICT-I life cycle, hence involving services associated to its deployment, plugging, use, maintenance, unplugging and undeployment.

4. ICT-I SERVICES

Actually the classes of services showed in the figure 3 (stressed below) correspond to the instance-of the ICT-I reference architecture that is being derived for the ECOLEAD project. New services can be added to and other can be withdrawn from the Federation according to a set of rules and policies, transparently to CNOs.

4.1 Horizontal Services

- CNO Actors On-Demand Collaboration Services. For supporting *human collaboration*, existing CSCW tools will be used to support the execution of the following services: mailing, chat, task list, file storage, notification, calendar,

wiki, forum, voice and syndication.

- CNO Knowledge Search Services. For supporting *knowledge sharing*, existing engines are being empowered to manage distributed and heterogeneous bodies of knowledge exposed by CNOs. Proper ontology and reconciliation rules have been used for bridging the semantic gaps among knowledge repositories allowing seamless retrieval of information.
- Interactive, user-centered BP Management Services. For supporting *business process interconnection*, on top of an existing open-source BPM environment (modeling module and execution engine), ICT-I will provide support to task-oriented, interactive decisional activities to be performed by CNO actors. The forthcoming BPEL4PEOPLE standard intends to be used for that.
- CNO Data Access Services. For supporting *systems interoperability*, ICT-I is developing an easy-to-use environment for WS-based legacy systems RDBMS query. This service provides tools for defining and configuring the database and the information that will be shared to a VO.

4.2 Basic Services

- ICT-I Security Services. These services aim to support confidentiality, integrity, availability and authentication in the communications. This includes the log-in and user management service.
- ICT-I Billing Services. It will allow the implementation of different billing models to support the pay-per-use and on-demand service provision.
- ICT-I Services Composition. This service will provide facilities to define and execute composed services according with BPEL standard for services composition.
- ICT-I Reporting Services. For supporting the generation of reports to other services (e.g. "detailed billing usage", "services bill summary"), using pre-defined templates in well known formats (pdf, XML, HTML, etc.).
- ICT-I Services Registry and Discovery. For supporting the publishing of the web services in a UDDI repository as well as the search and browsing of services.

5. THE FIRST ICT-I PROTOTYPE

A first prototype has been developed with the aim to not only test some services in consonance with the ICT-I reference architecture, but also to act as an initial testbed for testing some open source tools, the integration of different containers for web-services, the deployment of services in distributed sites, the performance of mobile access, and the use of portlets to support user interfaces. *Orchestration*, *Billing*, *Logging*, *Log-In* and *UDDI Registry and Browsing* were the main services so far implemented. An ICT-I portal was also implemented, allowing *end-users* and *system administrator users* to access different services regarding *security* configurations.

Web-Services/WSDL/HTTP/SOAP/UDDI have been used as the standard technologies to implement ICT-I. *AXIS / Jonas* and *JBoss* have been the containers used and services were coded in Java. Portlets were implemented in *Liferay* and *Stringbeans*. Services were deployed both on a Windows XP and Unix platforms, in three different countries.

In order to test this prototype a fake vertical service for partners search and selection was implemented. Via a simple VBE portal, the user makes queries asking for potential partners that can provide a given product in a certain amount. ICT-I services were deployed in different countries but this was transparent to the callers. At the end of the process the results with the list of partners that fit the "business opportunity" are presented for user decision-making. This result can be visualized both in the web portal and in a mobile phone. More details about this prototype and its preliminary assessment can be found in (Rodrigo et al. 2005).

Concerning deployment, it should be analyzed under two perspectives: server and client. From the *server* point of view, services are built as components so they need component containers to deploy them. As servers usually have this kind of container, this task is easily made. In the case services are tightly connected to legacy systems, this can be complex. ICT-I doesn't provide means to make this type of integration but it provides guidelines to assist IT experts for doing this regarding the main existing different communication mechanisms. From the *client* point of view, there are two main ways to access ICT-I: through a normal web browser or by a vertical service. The former is typically already deployed with operating systems so the user doesn't need to install any additional software. The latter means that the user needs to install the client application itself. In order to simplify the deployment (although this is to some extent out of scope of ICT-I), client application should be self-contained, i.e., all the required components should be bundled with it.

6. CONCLUSIONS AND NEXT STEPS

This paper presented an ICT infrastructure (ICT-I) for supporting CNOs in doing businesses. It has been conceived based on the service oriented architecture paradigm / web-services technology, providing organizations with a transparent (mostly), platform-independent, easy deployable and configurable, secure-embedded, lean, distributed, scalar, on-demand and pay-per-use ICT-I. The presented features and approach of ICT-I seems to make it somehow unique.

It represents the ICT-I being developed in the IST IP ECOLEAD project, which comprises three main types of actors / "ICT-I clients": Virtual Breeding Environments (VBE), Virtual Organizations Management (VOM) and Professional Virtual Communities (PVC).

ECOLEAD ICT-I does not intend to compete with or replace existing / commercial B2B frameworks, but rather to complement them with the value-added of CNO-related supporting services.

One of the basic strategies being applied is to use existing open-source software as much as possible and then to make the required adaptations for the ICT-I purposes. These adaptations are both at "application-oriented" level (e.g. knowledge and ontology management systems) and at "infrastructure-oriented" level (e.g. fault tolerance and some aspects of security). The selection of these softwares is currently under analysis.

ICT-I is still under development. Although it has already been used in the project, a number of conceptual developments and implementations will be made in the next future. This includes the implementation of all remaining ICT-I services and the integration with vertical services that are also under development, besides a

first set of test-cases close to real CNOs. In a posterior phase of the ICT-I development, attention will be put on evaluating and using existing frameworks in order to provide: i) supporting services for the management of the services federation life cycle, and ii) advanced searching mechanisms and semantic-driven services selection and composition over large-scale services repositories.

6.1 Acknowledgments

This work has been partially supported by the European Commission under the project IST FP-6 IP ECOLEAD project (www.ecolead.org) as well as by the Brazilian Council for Research and Scientific Development – CNPq (www.cnpq.br) under the project IFM (www.ifm.org.br). Special thanks to Mr. Rui Tramontin and Mr. Carlos Gesser (UFSC), Ms. Maria del Mar Rodrigo (Software AG Spain), Mr. Philippe Gibert (France Telecom), Mr. Roberto Ratti (TXT), and Mr. Walter Woelfel and Mr. Stanislav Mores (Siemens) for their collaboration in the conception and implementation of the ICT infrastructure. Also thanks to Mr. Luis Osorio (ISEL, Portugal) for his important insights and discussions about the ICT-I.

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