AN EVOLVING PLUG AND PLAY BUSINESS INFRASTRUCTURE FOR NETWORKED ORGANIZATIONS

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Abstract
This paper introduces 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 It is flexible to support an easy entrance of new services and the withdrawn of others.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 virtual breeding environments, virtual organizations and professional virtual communities. This paper details the ICT-I requirements, its architecture and services as well as implementation issues. Conclusions and current challenges are presented in the end.

Keywords: Collaborative Networked Organizations, ICT Infrastructure, Service Oriented Architecture, On-Demand, Web-Services, Reference Architecture, Interoperability, B2B, ICT Standards.

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 Organisations (CNOs) has been considered the discipline in charge of studying all the manifestations of organisations when they work in an inter-linked and organized way (Camarinha-Matos and Afsarmanesh, 2004). Organisations of diverse types have increasingly sought for establishing strategic alliances in order to deal with the survival requirements arisen with the globalization. A crucial requirement in today’s reality is agility. Agility has several definitions and can embrace a number of perspectives. In fact agility represents a deep change of paradigm in the organisations’ values and hence in the way they operate. Considering the elements presented by Jamali and Keshishian (2006), this present work sees them from a wider perspective, as showed in Figure 1.

From this agility angle, Virtual Organisations (VO) can be considered a very important manifestation within CNO: A VO is a dynamic, temporary and logical aggregation of independent and heterogeneous organisations (enterprises, professionals, governmental, NGOs, etc.) that collaborate with each other as a strategic answer to attend a given (short-term or long-term) business opportunity or collaboration need, and whose operation is achieved by a coordinated sharing of skills, resources, information and knowledge, totally enabled by computer networks (Rabelo and Klen, 2004). Actually VOs aim at supporting organisations to achieve exactly those new values comprised by the agile concept.

The realization of the VO concept comprehends several dimensions. In fact, acting as a collaborative organisation is not just a matter of wish. Instead, organisations must have diverse levels of preparedness. One of them is related to the supporting ICT (Information and Communication Technology) infrastructure. The implementation of any form of collaborative
network depends on this, allowing CNO members to communicate with which other in such way collaborations and businesses through the network can be supported and reinforced.

<table>
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<tr>
<th>Old values</th>
<th>New values</th>
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<td>Survival</td>
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<td>Efficiency</td>
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<td>Mass production &amp; standardization</td>
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<td>Stability</td>
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<td>Vertical, product-centric, static and fixed alliances</td>
<td>Horizontal, customer-driven, dynamic and temporary alliances</td>
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<td>Business Co-operation</td>
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<td>Centralized decision-making</td>
<td>Decentr. &amp; Distrib. decision-making</td>
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<td>Centralized, stationary and monolithic systems</td>
<td>Distributed / pervasive, mobile and service-oriented systems</td>
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Figure 1. Changes imposed by Agility in CNOs

However, 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 benefits of collaborative networks, more flexible and generic infrastructures need to be developed enabling networked organisations to agilely define and set-up relations with other organisations as well as to be adaptive according to the business environment conditions and current organisations’ autonomy levels.

All this has created a dilemma that modern organisations are currently facing: they start to be aware about the increasing need for handling inter-organisation collaborative processes but they can’t find technically adequate ICT-Is that are, at the same time, feasible alternatives and advanced and flexible enough to cope with the increasing ubiquity and diversity of evolving ICTs.

This is the essential motivation for the work described in this paper, presenting a model for a CNO supporting ICT infrastructure that can be complementary to and be integrated with the traditional B2B processes and systems, and that at the same time can be prepared for dealing with new ICT trends and challenges listed in Figure 1. This ICT infrastructure (ICT-I) is being developed in 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.

2. ICT-I REQUIREMENTS FOR CNO

When dealing with collaborative infrastructures it is important to consider the different nature and size of the organizations. In Europe, for example, more than 98% of the companies are SMEs\(^1\). As such, most of them have difficulties to have access to the main products of the market as they are complex, costly and requires high investment in supporting software, hardware and IT experts.

Nowadays, SMEs are generally informed about the importance to use ICTs as a driver for innovation as well as a mean to enhance the quality of their collaboration and so to augment their competitiveness. In fact, organizations’ managers are constantly riddled with plenty of software advertisements which claim to be the (collaborative) solution for them and it is very difficult to decide only based on this. Despite the benefits of collaborative work, practice has shown that the major challenge is how to create an organization culture where collaboration can become part of the process and not only an option of work. Another critic barrier is how to develop a collaborative infrastructure that makes users indeed confident and enthusiastic to use it in the support of their networked businesses.
There are already available software solutions and business frameworks in the market that offer some support for collaboration. 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 are complex to deploy and difficult to use. More than this, they haven't been designed to cope with CNO-related business processes. Actually, they support quite well traditional transaction-based business processes (purchasing, selling, shipping, etc.) among companies, most of them provided by ERP systems. In this type of processes, execution efficiency is the focus and processes are very well (and usually rigidly and a priori) modelled. In essence, such frameworks are basically process-centred.

Nevertheless, CNOs require an additional type of process, which can be called collaborative-based processes. They use to be interactive/user-centric, asynchronous and not necessarily well structured or defined a priori. Here the focus is on flexibility and adaptability. In essence, frameworks for that should be basically human-centred. Figure 2 lists just some and general CNO-related processes involved in a CNO of type VO that hence should be dealt by supporting ICT-Is.

![Figure 2. CNO-related collaborative processes.](image)

In resume, an ICT-I to support CNO should fundamentally provide functionalities associated to four types of actions: to enable people to collaborate and negotiate, systems to interoperate and adapt, knowledge and resources to be discovered and shared, and processes to be interconnected and synchronized. Therefore, an ICT-I for CNO – which is what this paper is about - is much more than offering groupware facilities to organizations.

In order to provide this support, there are several ICT-related issues that should be managed. In general, any organization wants to collaborate without noticing about the underlying ICT-I, i.e. using a totally transparent infrastructure. (SME) Managers want to make business, and not to spend time dealing with issues they usually don't know anything about it, like software deployment and low level configurations, setting up of security rights, different formats, downloading software, ontology specifications, etc., etc., which are often required by current B2B frameworks and corporate applications. Besides that, there are lower level features to support, like having an open, scalar and technology-independent infrastructure; federated information and resources management; flexible control mechanisms support for a large variety of behaviours; full e-transaction security and privacy; infrastructure reliability, among many others. All this has created obstacles whose practical result is the distance of SMEs from applying modern ICTs in their business routine.

A revision in the literature has revealed the inexistence of an ICT-I for CNOs and with that holistic and integrated sort of functionalities. In fact, what it has been observed is the development of robust supporting middleware and interoperability frameworks but which aims at improving the efficiency of traditional business processes. Examples of this involve the commercial B2B (service-oriented) frameworks developed by IBM, SAP, Oracle, Microsoft, BEA, Novell and Sybase. Important initiatives like ATHENA and INTEROP projects have focused on comprehensive models for tackling interoperability problems but also devoted to traditional business processes. More generic frameworks, like DBE and
ITSIBus (Osorio and Goncalves, 2005), have been more focused on the management of eco-services and lower level interoperability problems.

Developing a completely transparent, fully interoperable and totally reliable ICT-I to cope with all CNO requirements is however not possible considering the limitations of current ICTs even the most sophisticated ones. Besides that, CNO is an emergent area and many related issues are still gaining ground, which means the existence of several open questions yet. In this sense, the strategy adopted in the proposed ICT-I was to design a generic/reference architecture and flexible framework in a way ICT-I can evolve while newer CNO models and ICTs are introduced.

3. ICT-I RATIONALE

Considering the strategy mentioned above, the ECOLEAD ICT-I has been designed to be easy-to-use, lean, affordable, secure, evolving and independent of platform and technology. Figure 3 illustrates the usage scenario of the ICT-I and introduces its basic components.

ICT-I acts as a CNO collaborative bus, as a middleware, allowing different and distributed organizations to interact with another. As said before, the kind of interaction between CNO members comprehends diverse classes of elements: people, processes, systems, knowledge and resources. ICT-I functionalities are modelled as services (see sections below) and high-level applications (ICT-I clients) can have access to them via web portals and/or invoking ICT-I services directly. ICT-I can then be used as the ICT glue to link all those elements, including CNO members’ legacy systems.

ICT-I is not locally deployed. It is a totally distributed infrastructure whose services are accessed remotely and seamlessly, on-demand, on a secure base, from diverse services providers that are spread out over Internet, following some business models and performance criteria. In order to support this scenario, a number of key designing drivers has been taken into account. They are described in the next sections.

3.1 A Plug & Play ICT Infrastructure

The complexity of deployment and further utilization are typical reasons why people gets often sceptic for using good software available in the market or even developed in-house. Actually, there are so many other minor low-level tasks that are necessary to do when collaborating with other organizations that people prefer to keep on doing their activities isolated or without computing assistance. An essential principal of the ECOLEAD ICT-I is that it must be very easy to use in such a way users even can’t see it. The idea of a
transparent and plug & play environment was introduced by Muller and Nixon (2001) and it represents quite well the desired idea for the ICT-I.

In this sense, in order to use ICT-I, users and client applications basically need an ordinary web browser and Internet access – extremely common to exist in the organizations – as there is no local deployment. In spite of some current limitations in the available ICTs, most of interoperability problems are automatically and transparently solved on the fly thanks to several standards that are used (see next sections).

3.2 A Service Oriented Architecture ICT Infrastructure

There are a number of conceptual approaches that can be applied to support the ICT-I 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 and Huhns, 2005). 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. 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.

SOA allows a high-level of scalability, flexibility, reusability, integration, and it is a clear trend in software development. SOA approach is considered more suitable when services are (Singh and Huhns, 2005): standards-based, loosely coupled, shared, coarse grained, and under a federated control. As such, it is not suitable for all software projects. But the fact is that all major software vendors have bee adopting it in their most recent systems. Besides that, considering its potentialities, trends and ICT-I needs in terms of flexibility and scalability, SOA fits by far most of the requisites. In fact, SOA represents a new paradigm for systems design and integration and it leverages reaching the ICT requirements of the service oriented economy of the future and sustainable business networks.

Applying the SOA approach to ICT-I means that ICT-I is not a monolithic middleware as a “close world bus”. Instead, ICT-I is as a “pulverized” open and integrated bus composed of many distributed services allowing the integration of distributed / heterogeneous parts. That is the reason why it has been called CNO ICT infrastructure and not CNO ICT middleware.

3.3 An On-Demand ICT Infrastructure

Most of systems and B2B frameworks have been developed as monolithic packages of software. Regarding their increasing complexity and powerfulness, they have in turn required more powerful computer hosts and sophisticated people to maintain them. Reality has been showing that this is becoming a vicious cycle which is starting to create several difficulties for plenty of CNO members, mostly composed of SMEs. Worse than having to invest to host them, companies use to use only a very low number of the systems’ functionalities but they pay for the whole, no matter how much or how frequent they are accessed.

Thus, considering the essential nature of CNO members, their natural geographic distribution and mobility requirements, the ASP (Application Service Provider) model (Dewire, 2002) seems the most adequate for the ICT-I to support an on-demand concept. ASP provides a contractual software-based service for hosting, managing, and providing access to an application from a centrally managed facility. For certain periodically fee, the ASP provides content and other services for users connected through the Internet or any other network platform, and the users do not need to be concerned with software versions and upgrades. ASP provides access to applications that are located outside of the client environment. In essence, ASPs are a way of companies to outsource some or almost all aspects of their information technology needs.

The idea is to take advantage of the ASP concept and to adapt it to the CNO / ICT-I requirements, especially in what the infrastructure localization is concerned, i.e. to have the infrastructure accessed remotely. Traditional ASP is represented by a centralized application server, providing access to entire applications (i.e. with high granularity) and not to some of their functionalities separately. ICT-I, besides hosting and maintaining them, aims at
providing access only to the required functionalities to run a given business / collaboration. In other words, this means that ICT-I services are accessed remotely, upon request / on-demand, paid-per-use, based on a contractual software-based service for hosting, managing and providing access to its services, no matter where the services providers are and how services have been deployed. This gives rise to several business models to exploit ICT-I, as stressed in Borst and Arana (2005), making possible to offer an affordable and “made to fit” ICT-I for companies.

3.4 An Interoperable ICT Infrastructure
Interoperability plays an essential role in any infrastructure where CNO actors and their applications are distributed and heterogeneous. In this context, Interoperability is seen as “the ability of a system or a product to work with other systems or products without special effort from the customer or user. To achieve interoperability, interactions between organizations and their information systems should be considered at least at three levels: data, application, and enterprise/organization level, hence involving different enterprise architectures and different enterprise models, and take the semantics of data, applications and enterprise models into account. It is not only a problem of software and IT technologies. It implies the support of communication and transactions between different organizations that must be based on shared business references”9. Therefore, interoperability is a very wide area, which can comprise since low level sensors integration till higher levels of inter-organization collaboration.

Regarding the core focus of ECOLEAD ICT-I, interoperability aspects are covered only at its essentials, i.e. interoperability issues are tackled by each ICT-I service (see Section 4) according to its specific needs, also benefiting from existing software and approaches.

An extremely important enabler for interoperability is the use of standards. Large international initiatives (e.g. OMG, OASIS, W3C and TeleManagement Forum) have been creating specifications with large acceptance by software developers and vendors worldwide. Therefore, in order to mitigate interoperability problems, the ECOLEAD ICT-I has been fully developed based on ICT standards, independent of computer platforms. Yet, all the current available ICT-I services have been formally specified independent of technology, using the UML methodology, meaning they can be implemented in any language or environment. However, and as described in Section 4, ICT-I services have been implemented as web services, which is a particular technology. On the other hand, web services have been considered as a standard de-facto for implementing SOA-based systems and since recently newer specifications and initiatives (e.g. WS-I) have overcome initial interoperability problems among different specifications’ implementations of web services. An example of this is the WSIF14, which effectively supports the invocation / interaction among web-services deployed in different B2B frameworks. This is a powerful mechanism as it allows that different CNO members can also share their services between them (following security access rules) so enlarging collaboration no matter which environment has been used in the implementation of the services. It is to be highlighted that this endows ICT-I services to be integrated in existing organizations’ B2B portals in such way users can be complemented with CNO-related supporting services seamlessly (Piazza and Rabelo, 2007).

3.5 An Evolving ICT Infrastructure
A fundamental concept in the ICT-I is the so called Services Federation. A Federation corresponds to groups of devices and software components into a single, dynamic distributed system. 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, 1999).

Adapting this concept to the envisaged ICT-I environment means to see all services as members of a logical entity, the Services Federation. This federation comprises all (web) services that can be reached, used and shared among CNO members, involving the ones related with the ICT-I and its life cycle, the web-services-based applications, and (wrapped) legacy systems. Thus all existing services can coexist in a virtual logical repository of services and can be accessed transparently and seamlessly according to some rules. From
the ICT-I point view, users and applications don’t 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. Providers of such services can be both CNO members and independent software providers (“CNO of IT companies”), which can establish their own policies to manage the services repositories.

The presented ICT-I is seen as evolving as the Services Federation is a dynamic and self-manageable entity, with new members and services being incorporated to (or modified) and others being withdrawn from in a transparent way. This also means that a given service may have different implementations available over the network and thanks to smart services search and orchestration mechanisms the most suitable set of services for a given business transaction can be found out dynamically. This is however a challenge issue and some comments about it are given in the Conclusions.

3.6 A Secure-Embedded ICT Infrastructure
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 embedded in the ICT-I is flexible and declarative, allowing responsibilities (and eventually delegations) to be dynamically assigned to actors and required security mechanisms settled accordingly (Sowa and Sniezynski, 2007). It means that the access to the services (and information) of the federation by users and by other services is filtered considering the CNO actors’ privileges. Figure 4 illustrates the federation, which is composed of services provided by a number of organizations, and the visibility restriction of the CNO actors to access them.

Figure 4. Local Service Registries / Services Visibility

4. ICT-I REFERENCE ARCHITECTURE AND SERVICES

4.1 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 5). This architecture is composed of: Horizontal Services Layer and Basic Services Layer (Rabelo and Gusmeroli, 2006).
Horizontal Services correspond to common and general purpose services that can be useful to any kind of CNO. In the ECOLEAD project, three kinds of CNOs have been tackled: VBE (Virtual Organizational Breeding Environment [Afsarmanesh and Camarinha-Matos, 2005]), VO (Virtual Organization [Karvonen and Salkari, 2005]) and PVC (Professional Virtual Communities [Bifulco and Santoro, 2005]). These kinds of CNOs have specific needs for which application services (seen as Vertical Services) have been developed and that act as ICT-I clients. Horizontal services may be accessed by end-users directly.

These horizontal services in turn need lower-level services to support their execution, transparently (as much as possible) to the application services / CNO actors. These services are then seen as Basic Services and are domain-independent. Basic services represent the core and the transparent part of the ICT-I. Both horizontal and basic services are specified independent of technology and platform.

Although out of the ICT-I Reference Architecture, two other elements compose the framework: legacy systems and portals.

In the CNO and ICT-I contexts, legacy systems represent a category of services whose essential goal is to provide information about activities inside organizations to satisfy the needs of vertical services, like orders follow-up, performance evaluation, local schedule, etc. They use to be implemented in heterogeneous platforms and to have native front-ends so requiring specific wrappers for being accessed as services.

Portals act as optional integration front-end to the services themselves (their presentation layer) or even to other portals (as each CNO tends to have its own portal) as a way to invoke services directly by the end-user. Portals are however not services.

When seen as a whole, vertical, horizontal, basic and legacy services compose the Services Federation. 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 and layers they are placed. The set of services to be involved and the sequence of
their invocation / execution are configured via an orchestration / composition service by the vertical service’s designer.

4.2 ICT-I Services
This section describes the services presented in Figure 5 in a rough way. The implementation of some of them is stressed in Section 5.

Horizontal Services
Horizontal services are classified into four categories of services:
- **Human collaboration**: to allow collaboration among CNO partners via groupware services, like mailing, chat, task list, file storage, notification, calendar, wiki, forum, voice and syndication. It also includes services to support product development (CSCW) and files exchange.
- **Business process management**: to allow the modelling of business processes (their logic sequence, interconnection and synchronization) by users, their interoperability with different BP models, and the monitoring of the business processes execution by users and/or other systems (vertical services).
- **Knowledge and Resources discovery and sharing**: to allow CNO members to share their knowledge with other members, to search for given knowledge, and to have access to them according to access rights, including semantic mediation. Computing resources can also be shared among members and be found out as well. This service can be invoked by users and/or other systems.
- **Systems interoperability**: it involves a set of services to allow CNO members and/or systems to have access to information that is stored in the CNO members’ legacy systems seamlessly, including semantic mediations, as well as interoperability among different wireless and pervasive network protocols (specially for services adaptations).

Basic Services
Basic services are classified into ten categories of services:
- **User’s representative**: services involved in representing users in collaborations when they are busy or absent, e.g. avatars and their configurations.
- **QoS**: services involved with Quality of Service, such as security services (authorization, authentication and accounting), fault tolerance and real-time supporting services.
- **Billing**: services involved with billing collaborative transactions following configurable business models that can be associated to individual services.
- **Services behaviour**: they involve the set of services for configuring the functional and coordination aspects of the services in their execution. In the web services contexts, this is related to services composition, orchestration and choreography.
- **Services management**: they are services to manage the services lifecycle that will be made available in the services federation. This involves services registration, discovery, browsing, auditing, withdrawn, as well as the services federation rules management.
- **Services brokerage**: services involved with services search and selection.
- **Reporting**: services to support reports generation, to used by billing or auditing purposes.
- **Knowledge management**: services to support the management of the knowledge that will be available for CNOs and the involved ontologies. Machine learning-based services can also be used to support CNO/VO inheritance.
- **Users interface**: services that are responsible for offering some support to generate services’ GUIs as well as to support the GUI adaptation according to contexts and devices.
- **Resources virtualization**: supporting services to allow an extended level of collaboration among services and users, providing means to share hardware (mainly hard disk and memory) via, e.g. grid computing platforms.
- **Stubless invocation**: to allow seamlessly services interoperability when deployed in different SOA-based frameworks.

This description of the horizontal and basic services categories of services is evidently very general. The goal is to give the core idea of each one as their detailed scope and behaviour can only be specified when they are designed and implemented. In fact, this is
related to the derivation process. In the enterprise context, the concept of derivation has been applied by some more recent relevant initiatives, like VERAM (Zwegers and Tolle, 2002), which acts as a methodology to drive the derivation process of virtual enterprises from a reference architecture to a particular architecture. Another example is ARCON (Camarinha-Matos and Afsarmanesh, 2006), which extends the virtual enterprise concept to CNOs in a wider reference framework, even though without offering some methodology to derive particular CNOs. It can be said that the ICT-I Reference Architecture is positioned at a lower level. It complements those initiatives as it can be seen as a result of a derivation process in terms of supporting infrastructures. Under this perspective, this architecture can be used in two different purposes. It can be used to derive particular services/functionalities of ICT infrastructures for specific CNOs, but it can also be applied as a reference, as a global map, to guide which developments are required for general CNOs.

5. ICT-I IMPLEMENTATION

This chapter depicts the issues related to the implementation of the ICT-I’s services.

5.1 Implementation Rationale

As stressed in Section 3.2, ICT-I has been fully developed applying the SOA paradigm, i.e. its functionalities have been implemented as services. More specifically, using the web services (ws) technology.

As mentioned in the previous Section, the boxes in Figure 5 refer to categories of services that should be further renamed and implemented applying given technologies. Thus, a number of functions, services, classes, procedures, etc., can be used to code each one of the categories as well as different levels of interaction with a user (if any) can exist, also depending on the way these categories are implemented. For instance, in the current implementation of ICT-I services and the way their behaviours were thought, horizontal services usually have some direct interaction (via user interfaces) also with the end-users, whereas most of the basic services are directed invoked by other services. In some cases, there is also some interaction with systems administrators.

Other implementations of the same service category may present totally different behaviours depending on the business rules that should be observed in a given derivation. This means that multiple different implementations of the same category of service may exist and hence co-exist in the services federation. According to business models and agreements, smart mechanisms for services discovery and selection, performance criteria, among other aspects, the appropriate set of services are identified for the execution of given business processes.

An important strategy used in the ICT-I implementation has been the utilization of already existing supporting open software has been used and adapted in some cases. For some other cases, services were developed from scratch.

Another strategy was to provide means to ICT-I in order to be integrated with B2B frameworks with which enterprises have deployed their systems. This means that users and systems placed in their local environment can also have access to ICT-I seamlessly so providing means for a more complete business environment, integrating traditional business processes and collaborative-based business processes. This has been achieved thanks to the strong use of standards, as mentioned in Section 3.4. Therefore, the ICT-I, although SOA-based, is designed to have connections with legacy systems and other corporate systems, i.e. it should also deal with enterprise integration approaches. For example, legacy systems should be wrapped (as a ws) in order to be accessed, similarly to EAI (Enterprise Application Integration) approaches. Therefore, it can be said that ICT-I is positioned somehow in between SOA and Enterprise Integration approaches.

5.2 Implementation ICTs

All the implemented web services have used other auxiliary technologies, namely WSDL as the services’ interface, HTTP and SOAP as the communication protocols, and UDDI for services registration. AXIS, Jonas and JBoss have been the containers used and services
have been coded in Java. The services’ presentation layers / user interfaces are programmed as *portlet*, using *Liferay* and *Stringbeans* (as the presentation layer is an independent part of the services, it can be programmed using other technologies, like *struts*). Services were deployed both on Windows XP and Unix platforms, in different remote servers. There are other functions that are not truly web-services but offer transparent support for the existing services. The function (called *interceptor*) that identifies and parses each transaction for billing purposes, the ones that get linked to the services for supporting seamless dynamic services invocation, among others, are examples of this.

As all services of the ICT-I are registered and deployed in remote servers it is not necessary to install anything to be plugged. Actually, the only thing that is necessary is some customizations in a small part of the security services in the first time in order to get a digital certificate and to be recognize in a given CNO. Concretely, users can get plugged and to further play in three manners:

- A given organisation’s application can invoke ICT-I services directly hence indirectly and transparent for users.
- If the organisation already has a portal, it can be organized to invoke horizontal services directly, interacting with them via their user interfaces (services’ portlets).
- If the organisation doesn’t have a portal or its portal is not build modularly, users can invoke (horizontal) services directly via their common browsers. In this case a new window will be showed presenting the service’s interface.

5.3 ICT-I Services

Current status of already implemented ICT-I comprise the services below. Every single service is completely specified in UML (e.g. use cases, class, sequence and deployment diagrams) (Ratti and Rabelo, 2007), uses different software tools for its support (Rodrigo and Ratti, 2007), and has its ws interface (WSDL). As mentioned in the previous section, some services have a user interface and some services don’t. As it is not possible to describe in details all services, one user interface of some services will be shown and one service will be more detailed stressed.

**Horizontal Services**

- **Groupware services**: mailing, chat, task list, file storage, notification, calendar, wiki, forum, document management, voice, news and syndication. Figure 6 shows one of the user interfaces of the document management and news.

![Figure 6. Document Management and News User Interfaces](image)

**CNO Knowledge Search services**, For supporting *knowledge sharing*, allowing that any published document in any format can be searched and retrieved from the CNO’s
members. Proper ontology and reconciliation rules have been used for bridging the semantic gaps among knowledge repositories providing seamless retrieval of information. Figure 7 shows one of the user interfaces of the knowledge search.

Figure 7. Knowledge Search User Interface

- **Business Process Management services.** Group of services for supporting *business process modelling and monitoring*.
- **CNO Data Access services.** For supporting *systems interoperability*, this service is an easy-to-use environment for querying ws-based wrapped legacy systems RDBMS. This service provides tools for defining and configuring the partners’ databases and the information that will be further shared with the CNO.

Actually, considering that information is essential for (SOA-based) processes execution (e.g. VBE/PVC management, VO/VT management), there are different sources of information to which ICT-I should then allow (seamless) access. CNO Data Access services act as middleware used between the physical data sources and the data used by the different services. It provides an abstraction for the data used in the CNO. This is important as each CNO/VO member has its own data structures and sources so it is necessary to create a common schema or data model that can be understood by all the involved members at their SOA applications level. This data layer provides loose coupling between the services and the underlying databases / information sources, and it also deals with the different semantics of each provider thanks to some configurable mapping. The Data Access services transform the specific providers’ data into the common one by hiding the specification of each data.

Data Access functionalities and modules comprised in this service are the following:
- Definition of the common schema, called "Domain model".
- Schemas and guidelines for different data adapters (i.e. for different formats) (Figure 8). The most relevant adapters are “Data-adapter for Relational DBMS”, “Data-adapter for XML files” and “Data-adapter for Web Services”. These adapters access the information source (RDBMS, XML files or data come from a ws), gets the data and transform it into the domain model structure, known by the members (as they share a reference information model). RDBMS is a special case because it could be considered as providing access to legacy databases, which usually contains important data that are not always accessible by external Web Services. Relational database adapter provides a Web Service interface for accessing to data stored in RDBMS by means of a general interface where the user of the WS (usually an application) can define the data it needs. The service translates this query into a query understandable by the RDBMS, and launches it in order to provide the required
data to the user. This offers interoperability as high-level process can work using the same model.

- Creation of the relations and links between the “domain model” and the existing Web Services. In particular, support to the mapping and relations creation between the “domain model” and the relational data base.
- Web services providing data from different data sources (data retrieval), offering a common data model.

![Figure 8. Data Access component diagram](image_url)

**Basic Services**

- **ICT-I Security Services.** This involves a set of services to support confidentiality, integrity, availability and authentication in the communications. This includes the log-in and user management service. One of its user interfaces is shown in Figure 9.

![Figure 9. Security User Interface](image_url)

- **ICT-I Billing Services.** It allows the implementation of different billing models to support the pay-per-use and on-demand service provision.
- **ICT-I Services Execution.** These services provide facilities to compose, orchestrate and
execute services, modelled in BPEL.

- **ICT-I Reporting Services.** It supports 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 Registration, Browsing, Discovery and Withdrawn.** They offer means to publish the web services in a UDDI repository as well as to search, browse and delete services.

### 5.4 ICT-I Deployment

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 such containers, this task is easily made. In the case services are tightly connected to legacy systems, this can be very complex, and ICT-I doesn’t provide means to make this type of integration. However, 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 / high-level application. 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. In order to simplify the deployment (although this is out of scope of ICT-I), client applications should be self-contained, i.e., all the required components should be bundled with it.

Figure 10 shows an example in UML of a deployment scenario of the ICT-I. It is important to remember that the deployment scenario for a particular instantiation can be extremely variable. By absurd, both ICT-I services and vertical services can be registered and deployed in only one server or every of these services can be registered and deployed in distributed machines. In this hypothetic case, there would be three computers belonging each to three organisations (A, B and C) and four servers:

- **VO portal server:** it hosts a given VO portal software;
- **Basic server:** it hosts basic services, namely Billing and the BPEL Engine as well as composed services (orchestration);
- **Horizontal server:** it hosts CSCW services and the Knowledge Search services.
- **Vertical server:** it hosts vertical services.

![Figure 10. Example of ICT-I Deployment Scenario](image-url)
About the relations presented in this diagram are, some relevant aspects need to be pointed out. First, the organisations use their own web browsers to access the VO portal, which in turn accesses basic and horizontal services. Other aspect is the access to Organisation “C”’s legacy database. This is done by the Data Access Service (deployed locally) which provides the required data to other services and applications (in this case, to Vertical Service “B”). Finally, Organisation “B” contains a client, called Client “X”, which has access to an orchestrated service, composed by Vertical Services “A” and “B”.

As already said, this is a possible deployment configuration. In this case, all services for supporting the VO (ICT-I and vertical services) are hosted externally by third parties, on categorized servers (horizontal, basic, portal and vertical). Many other configurations are possible. Services can be deployed only in VO partners’ computers, or in a centralized server, or even in third part providers, in one or several physical servers.

6. CONCLUSIONS

This paper has 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 organisations with a transparent (mostly), platform-independent, easy-to-use, secure-embedded, lean, distributed, scalar, on-demand and pay-per-use ICT-I. The presented features and approach seems to make ICT-I somehow unique. So far it is being developed and validated in the IST ECOLEAD project, considering three types of CNOs: Virtual Breeding Environments (VBE), Virtual Organisations (VO) and Professional Virtual Communities (PVC). Supporting CNOs imply in a different set of functionalities, meaning that ICT-I complements B2B functionalities as well as it adapts traditional groupware functionalities to a CNO environment. On the hand, thanks to the ICT-I framework flexibility and strong utilization of standards, all these functionalities can be integrated in a same computing working environment so that users don’t need to see them as separately systems.

From the technological point of view and following current trends, ECOLEAD ICT-I has as main features:
- It is a web-based platform, meaning that users should only have a browser and Internet access. No local deployments.
- It is a Service Oriented Architecture-based (SOA) platform, where all of its functionalities are implemented as software services that are distributed in services repositories.
- Plenty of new services can be added without any interference in the use of the infrastructure, also meaning that ICT-I can intrinsically evolve.
- Services are accessed on demand (like the ASP model) and can be found out in a clever way, according to the business process flow. This means having almost an “a la carte” environment to fit each organization’s needs.
- Services are paid per use (under several business models).
- (Some) Services can also be accessed through mobile devices.
- Services and data access are dynamically controlled by a flexible security system.

Regarding its CNO orientation and other features stressed along the paper, it is believed that ICT-I is unique and it clearly goes towards supporting several requirements of Web 2.0.

From the technological point of view, the chosen web-based technologies have proven to be a good choice. Adding the fact that the development environment was settled in advance and hence most of partners have used the same one, the integration of the services (vertical, horizontal and basic) was carried out relatively smoothly. Once all services’ interfaces, parameters, UDDI, etc., were properly set up, all invocations – and hence the CNO processes – were executed without problems even having services physically deployed in several countries. Therefore, from the conceptual point of view, the ICT-I as a distributed WS-based infrastructure seems to be a feasible approach. On the other hand, it has to be pointed out the complexity of developing web-services-based applications. In fact, the related standards are capable to cope with relevant interoperability problems so implementations can be concentrated on the services themselves. However, to become a reasonable expert on web-services, it takes time. The involved platforms, containers, development
environments, the several concepts around UDDI, WSDL, SOAP, portlets, etc., are very time
costing to learn and require a relatively solid ICT background to implement services in a
good and fast way. Another point refers to the identification of limitations in some specific
technologies, e.g. the relative rigidity of LifeRay when more flexible GUIs are required.

From the performance point of view, it could be observed that some services took a
relatively long time to execute. From one hand this is also due to the complexity and to the
required processing time needed by some of them. On the other hand, the deployment “map”
of the whole ICT-I was set up essentially considering the current partners convenience and
facilities as QoS considerations were not hard taken into account yet. Besides this, this
problem tends to decrease while the quality of Internet infrastructures improves and fast
Internet connection begins to become the normal and not an exception in the SMEs world.

Some elements of the security framework are still centralized, causing the known
consequences to the whole system. In the future, when large-scale will exist, distributed and
trustworthy repositories will be a must to exist as well as a more careful analysis of the most
suitable topology of repositories should be done.

From the collaborative business process point of view (i.e. at high-level applications /
vertical services level), using some demonstration scenarios as a basis, no problems took
place besides the normal ones during testing phase where parameters, etc., had to be fine
tuned for the correct services invocation. The effectiveness of this in real cases of companies
should be however further evaluated.

ICT-I is still under development and a number of conceptual developments and
implementations will be made in the next future and requires more attention. Web-service
technology, despite its potentialities and increasing acceptance, has some drawbacks (e.g. it
is stateless) that should be managed depending on the desired business process’s
behaviour. Dealing with large-scale fault tolerance problems is still an open and very
complex topic of research so it is expected that future outcomes of this can be incorporated
in the ICT-I. Another complex issue is the management of the services federation. Each
service provider can determine its own operational and security rules besides having
different levels of computing infrastructures to run services, which can create serious
troubles and to lead to other class of interoperability problems when several providers were
established. Moreover, the operational policies should deal with the different life cycle of
each service that is made available, which is also complex. Services should be easily
discovered and immediately integrated / bound to workflow or orchestration systems
mechanisms, but this bumps into in the different ways and semantics the diverse providers
have registered the services, on how the services interfaces (WSDL) are expressed, and if
context awareness has to be considered. All these difficulties represent challenges in the
web-related community in spite of several ongoing works. Two interesting research projects
that can be mentioned and that are dealing with some of those problems are DBE
(www.digital-ecosystem.org) and ABILITIES (http://services.txt.it/abilities), but their results
are still not at a level for being right used.

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