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Managing Inter-Enterprise Information Exchange in Construction VOs

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Abstract
The typical operational modality of a construction project is that of a virtual organisation. Within such contexts, different organisational entities share competencies to deliver a one-of-a-kind product or service. This paper presents a typical VO (virtual organisation) environment in the form of a seven layered ICT architecture that supports the definition and mapping of an organisation's internal system within a shared inter-enterprise context for VOs. An ICT system based on a set of system components is furthermore presented to provide a illustration of the operational environment of a typical VO.

Keywords
Virtual Organisation, Layered Architecture, System Components, Inter-enterprise Collaboration

1. Introduction

One of a kind product or service delivery (e.g. construction of a building or facilities management) increasingly demands the one-time collaboration of different organisations to consolidate and synergise their dispersed competencies in order to deliver a desired product or service. This naturally has an implication not only in the way information (related to the to-be-delivered product or service) is exchanged and shared, but the way in which secure, quick to set-up, transparent (to the end-user) and non-intrusive (to the normal ways of work of an individual/organisation) ICT is used for this purpose. This has been a central research theme in various research initiatives (a listing of more than 100 European projects can be found by selecting "Virtual Organisation" at http://cic.vtt.fi/links/euproj/index.html).

Clients today demand customised products and services that a single organisation may not be able to deliver. These specialised products and services can be delivered through competence sharing between several different organisations. A virtual organisation (VO) is then formed to deliver the product or service. For organisations participating in a VO setting, the (ICT) challenge is information exchange between heterogeneous applications and services. This exchange of information should be in a transparent and controlled manner. How for example, can an individual organisation access and integrate information from multiple (external) sources while only exposing relevant parts of its own information.

2. Background to the Construction Industry

Construction is the largest industrial sector in the EC, with gross output representing approximately 11% of Community GDP and 5.6% of the value added. It is also the largest sector in terms of employment, providing jobs for some 7% of the working population, and it is a key sector for job creation with every job created in the construction sector generating two further jobs in related sectors (European Communities, 1997). The European construction industry does not, however, have a single cohesive identity; rather, each member state operates within varying economic and physical climates, is governed by differing regulations, uses different forms of contract, displays organisational and cultural differences, and so on. Since the Industrial Revolution, the construction process has moved away from individuals ('master and servant') to complex interactions between companies via processes throughout which many different systems are involved. Furthermore, construction industry actors have increasing potential to exploit international opportunities.

The construction lifecycle covers an unusually long timescale in terms of the manufacture and useful life of an artefact, from the initial idea and requirement for a construction facility, through to its final destruction. Furthermore, each construction project is a prototype as it differs in many respects from every other, and as the product is so durable (and with a high capital value) it is usually repaired or altered rather than being disposed of and replaced.

Much research has focused on processes within the construction industry, both throughout the building lifecycle and also within specific phases (Kagioglou, et al, 1998, Kamara and Anumba, 2000). The assertion is that both efficiency gains will be made, and client business needs better met, if all actors within a project can work to an agreed set of processes and procedures. Problems with co-ordination, collaboration, communication, documentation and so on, rely on integrated processes between construction project actors. In summary the important characteristics of the construction industry include:

- The sector is heterogeneous and highly fragmented, depending on a large number of very different professions and firms, predominantly small/medium size enterprises (SME).
- It is one of the most geographically dispersed sectors.
- Construction is highly project oriented, and any ICT used within a project must be deployable and profitable within one project to all/several partners.
- Teamwork is predominant in the industry, requiring all actors involved to work effectively together in cooperation.
- Each construction project is unique.
- The sector is highly regulated; rigorous regulations and standards involve several levels of governments (local, provincial, national).
- The sector is very labour intensive, with high mobility of the workforce.
- Business relationships are temporary and often short-term, bringing together partners who may never work together again.
- All actors are involved in numerous projects at the same time.

The characteristics above are a clear indication that the construction industry has in fact adopted the modus operandi of the VO for decades. What it hasn't achieved however, is an effective and widely adopted reconfigurable ICT enabled solutions delivery system. There is still a need for the integration of differing technologies and effective communications.

3. ICT Architecture and System Components for Construction VOs

A key research endeavour has been the definition and development of an ICT architecture and corresponding system components that may be used for construction VOs. This was a major undertaking in EC projects GLOBEMEN (http://cic.vtt.fi/projects/globemen) and OSMOS

(http://cic.vtt.fi/projects/osmos). The following sections present the ICT architecture and corresponding ICT system components.

3.1 ICT architecture

A simple seven layered ICT architecture (
FIG. **1**) was defined (Kazi, et al, 2001 and Kazi and Hannus, 2002). Its main purpose was to act as a mapping template upon which organisations could map their in-house applications, interfaces to shared VO environments, communication protocols, and shared services used. This architecture was validated and used by all end-users in GLOBEMEN.

1. *Presentation layer:* This layer provides the user interface through which individuals gain access to VO information depending on their roles in the VO partner organisation. (Example: web page providing access to the projects in which a person participates). This layer is (in an ideal case) configured by the organisation which the individual represents.
2. *Application layer:* This layer consists of applications that a user needs to perform tasks for specific VOs. It essentially includes application software of the VO partner organisation. (Examples: ERP, CAD, cost estimation, etc.). This layer is generally quite static and independent of a specific VO.
3. *Interoperability layer:* This layer acts as the data/information mapping and translation mechanisms between an organisation's applications and the shared VO environment. It may provide semantic and syntactic mapping to VO standards, release management, assigning VO level access rights internally within the partner organisation, etc. (Examples: conversion software that translates proprietary data format to a standard format, making officially released information available to the VO). This layer usually needs to be configured for each specific VO.
4. *Communication layer:* This layer enables communication between (the ICT systems of) an organisation and the shared workspace of the VO. Thereby, this layer addresses both the geographic and organisational distribution of VO partners. (Example: the Internet, data exchange and communication protocols, data formats etc.). This layer relies mostly on standards and commonly available technologies.

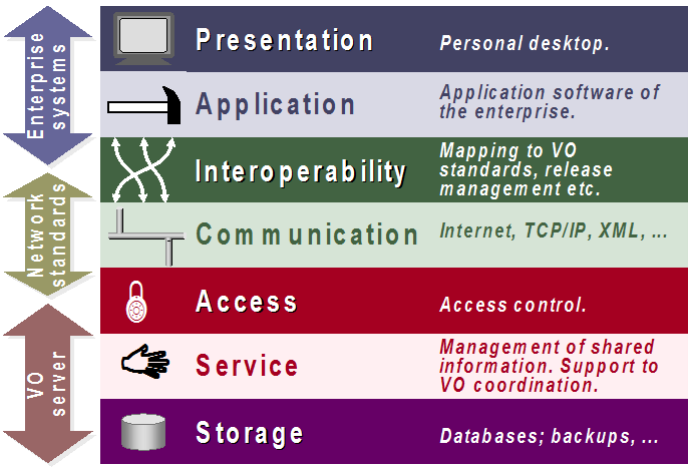

FIG. 1: Seven layered ICT architecture

5. *Access layer:* This layer controls the access to the shared VO workspace and information. It provides/regulates management of VO member roles and profiles. (Example: user identification, access rights management).

6. *Service layer:* This layer provides access to and management of shared information and services to the VO. (Examples: document management, product model management, inter-enterprise workflow management, notification of new/changed information etc.).
7. *Storage layer:* This layer hosts the main system registry and repository. (Examples: databases, backup procedures, etc.).

When mapping onto this architecture (Figure 1) it should noted that certain elements (applications/services) may span across more than one layer.

3.2 System components

The envisioned environment for the VO (Figure 2), contains several distinct components. A short description of the components and their mapping onto the seven layered architecture (Figure 1) follows:

- *Personal Desktop:* This is the main interface through which an individual interacts with both his/her organisation's in-house working environment and other sources (e.g. the VO). Some applications may reside on the desktop itself, whereas others may be accessible in the form of online services. The personal desktop maps well onto the "presentation layer" of the seven-layered architecture. Of course, certain applications on the desktop may also extend to other layers, e.g. application and/or interoperability layers.
- *In*-house *working environment of a company:* This is where most of the internal applications and services of the organisation reside. The corporate intranet, would be one such example. This component, maps mainly onto the "application layer" of the seven-layered architecture. It should be noted that "within" the enterprise this component could also act as a "local" VO environment. In such cases its mapping onto the whole seven layered architecture would be justified.

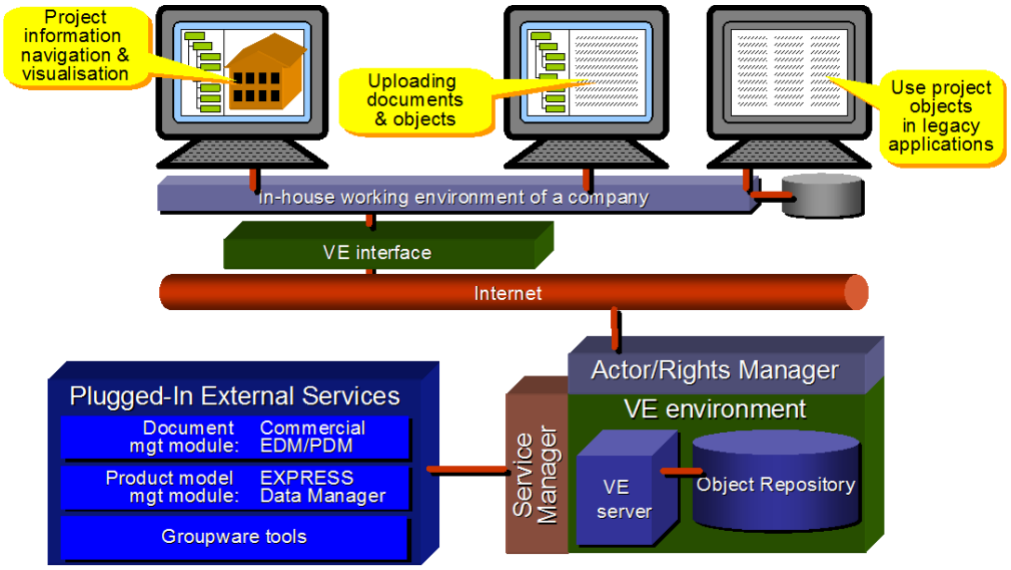

FIG. 2: System components

- *VO interface:* This component mainly acts as a mapping agent/translator between an organisation and the shared VO environment that it uses when participating in a VO. It provides for release management and regulates what information is sent by the organisation to the shared VO environment. The VO interface may be mapped onto the "interoperability layer" in the seven-layered architecture.

- *Internet:* The Internet here acts as the main communications channel between the enterprise and the shared VO environment and associated services. It may be mapped onto the "communication layer" of the seven-layered architecture.
- *Actor/rights manager:* This component deals with basic access control and provides access to those services that an individual (or organisation) have rights. It can be mapped onto the access control layer within the seven-layered architecture.
- *VO environment:* This contains the mechanisms to manage access control, plug-in services, management of shared information, etc. In many cases, this acts as the shared "project server" that many are familiar with. The VO environment maps onto the "Access", "Service", and "Storage" layers of the seven-layered architecture.
- *Service manager:* This component handles the registration of, access to, and management of external services. It can be mapped onto the service layer of the seven-layered architecture.
- *Plugged-in external services:* The IT needs may vary from one VO to the next. This variation is primarily in terms of the shared services that are required for the VO in question. In most cases, they do not need to be developed from scratch, but may be plugged-in. In some cases however, adaptors may be required to enable the "plugging-in" of some specific external service. Some examples of such services are indicated in Figure 2. This system component (plugged-in external services) may be mapped onto the "Service" and "Storage" layers of the seven-layered architecture. In most cases, access to these services will be managed by the service manager and regulated through the VO environment.

5. Conclusions

Client demands for one-of-a-kind-products and services are fostering competency sharing and collaboration between different organisations to deliver these products and services. Each organisation is typically involved in the delivery of one or a few components of the requested product or service. To deliver the complete product or service, organisations need to rely on each other for information completeness, as all product components are inter-related. This is giving rise to demands for inter-enterprise collaboration tools that allow an organisation to transparently share and exchange relevant product/service related information with other organisations.

This paper presented an ICT system architecture consisting of seven layers that can be used as a basis for mapping intra-enterprise systems within the use context of inter-enterprise settings. An ICT system based on a set of generic system components was furthermore identified to illustrate the operational environment. Both the ICT architecture and system components were validated and used within the GLOEMEN and OSMOS projects respectively. It was observed that both are generic in nature and applicable to VO environments in other industrial sectors as well.

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