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TECHNOLOGY INFRASTRUCTURE FOR VIRTUAL ORGANISATION OF TOOLMAKERS

John Mo
Commonwealth Scientific and Industrial Research Organisation, John.Mo@csiro.au
AUSTRALIA
Ron Beckett
Reinvention Network, rcb@reinvent.net.au
AUSTRALIA
Laszlo Nemes
Commonwealth Scientific and Industrial Research Organisation, Laszlo.Nemes@csiro.au
AUSTRALIA

Globalisation has forced companies to work together in a new arrangement known as virtual enterprise. An Australian initiative called RELINK aims to demonstrate the methodologies and systems, that will enable small firms in the tooling and automotive industry to participate with medium and large firms in turnkey projects as part of a broader supply chain. The initiative draws on this body of knowledge in conjunction with research and university partners and concentrates on the practicality of the formation of virtual enterprises in the tooling and automotive industries competing with larger toolmaking companies globally. This paper explores a 5 layer open communication framework for virtual enterprise to establish a continuity of functionality in the communication process that enables B2B operations within a virtual enterprise with varying levels of communication capabilities. The framework identifies options for bridging gaps in communication functionality between the desired application level and the varying situations of the participants.

1. INTRODUCTION

Globalisation has forced companies to work together in a new arrangement known as virtual enterprise. This is characterised to be flexible, dynamic with minimal or sometimes no contractual agreements among the partners. A virtual enterprise can be created and disbanded in very short time frames. Interactions at organizational, technical, social and commercial levels give rise to emergent properties that have specific technical, communications and infra-structural issues. These issues have been investigated in many research projects in the last decade and a vast volume of information can be found in literature (Williams *et al*, 1994, Callaham, 1996, Bernus *et al*, 1997). The Australian "RELINK" initiative aims to demonstrate the methodologies and systems that will enable small firms in the tooling and automotive industry to participate with medium and large firms in turnkey projects as part of a complex supply network. It draws on the body of knowledge of virtual enterprise in research and university partners and concentrates on the practicality of the formation of virtual enterprises in the Australian tooling and automotive industries competing with larger toolmaking companies elsewhere.

In a typical virtual enterprise, a large amount of data transfer and real-time coordination is necessary to ensure fast turn around time of activities. Achieving this outcome involves sharing sophisticated applications across offices irrespective of whether they are in the neighbourhoods, far away cities or sometimes continents. The use of ICT to carry large amount of data is a critical factor making the virtual enterprise a success. Therefore, one of the focal points of study in RELINK is on the application of ICT tools among members of the toolmaking virtual enterprise and the effectiveness of these ICT tools on collaboration and enhancing business opportunities. This paper explores the issues and considerations that will be evolving in the project.

2. COMPATIBLE COMMUNICATION MODEL

It is observed, in various roadmapping studies, that communication technology level in SMEs varies greatly between companies (Beckett *et al*, 2003, Barradas *et al*, 2004). However, technology level affects the effectiveness of communication between two parties. Communication by fax is obviously inefficient as compared to electronic data transfer or emails. Likewise, a highly automated internet communication channel will be a good choice for some but not other toolmakers. Some of the computer technologies such as CAD-CAM, CSCW, multimedia, data exchange standards and PDM systems are affordable only in medium sized companies. The RELINK project objective of linking tooling/component manufacturer teams of medium sized companies in mobilizing the capabilities of a large number of small companies linked with the medium sized ones will have particular difficulty in overcoming the communication issue.

To develop the conceptual framework, we make reference to the international standard Open Systems Interconnection (OSI) model (ISO, 1983). The OSI model is a framework for communication between computers. The model establishes the elements in the communication framework to handle complex situations such as noise in connection, error processing, detection, request for re-send, language and conversation synchronization. The fundamental principle of OSI is to divide the functionality of the communication system into smaller sections so that the problems can be confined to specific issues when the communication modules are developed. The sections are known as layers, which have defined functions to be fulfilled by any system claiming to comply with the standard.

Another important characteristic of OSI is its peer-to-peer communication process. OSI evolves from the concept of distributed communication services. Each layer has a defined set of rules that governs successful communication procedures and formats between communicating entities located at the same layer in two different systems. The set of rules is referred to as a communication protocol. Hence, two entities at different layers cannot communicate but will be able to do so through their compatible layer components in the system. There are three consequences:

- Both sides must have all 7 layers in order to communicate properly between applications;

- If one side does not have full 7 layer functionality in the system, it will receive information at its highest layer. A separate process is required to process the information at that layer to the application layer.
- If both sides do not have the full 7 layer functionality, the two systems will communicate at the lower of the highest layer available in the two systems. The two systems will have separate internal processes to convert information at that layer to their application layer.

It is necessary to point out that the functional modules can either be software, hardware or a combination of both. All levels (except the physical connection) can be implemented in software and equally, all levels can be implemented in hardware. Hardware modules tend to be used for lower level applications in the OSI model due to the simpler functionality. However, as many hardware devices are now made programmable, the distinction between hardware and software modules is not important in computer network elements nowadays.

3. THE VIRTUAL ENTERPRISE REFERENCE ARCHITECTURE

The modelling of virtual enterprise has been studied in a number of international projects (Hsu *et al*, 1994, Pan *et al*, 1991). The most well-known project is the IMS project GLOBEMEN which defines the Virtual Enterprise Reference Architecture (VERA) (Zwegers *et al*, 2003). VERA, which originates from Generalised Enterprise Reference Architecture and Methodology (GERAM) (Bernus *et al*, 1997), illustrates the logical, recursive relationships between the network entity, the VE entity and the product entity. Each of these three entities is represented by a life cycle describing possible phases an entity can be in throughout its life span from identification to decommission. VERA illustrates that the network can create VEs in its operational phase and, correspondingly, that a VE can create products and/or services in its operational phase.

The important characteristic of VERA is the changes of architecture requirements in different phases of the virtual enterprise. Conceptually, there are 3 architectures: Information Systems, Manufacturing Equipment and Human and Organisational architectures. Information systems and manufacturing equipment architectures represent automation of information and materials flows. Human and Organisational architecture sits between the two architectures and serves as the operating centre of the virtual enterprise. It is essential that a balance is required to ensure all three architectures are running in supporting each other rather than one moving too far (or behind). Individual companies may vary the balancing point (known as "extent of automation") but in a virtual enterprise, collaborative partners must find a common acceptable extent of automation. In essence, the "extent of automation" defines the ICT level at which the virtual enterprise is to operate.

4. THE RELINK COMMUNICATION FRAMEWORK

We use the OSI and VERA concept to consider the communication process between two toolmakers or a toolmaker and his/her customer. A 5 layer model can be used to describe the functionalities required to carry out the tasks transmitting information from one end to another. This model is designated as RELINK Communication Framework (RCF) as shown in Figure 1. Note that the case of customer to customer is not in the scope of this study.

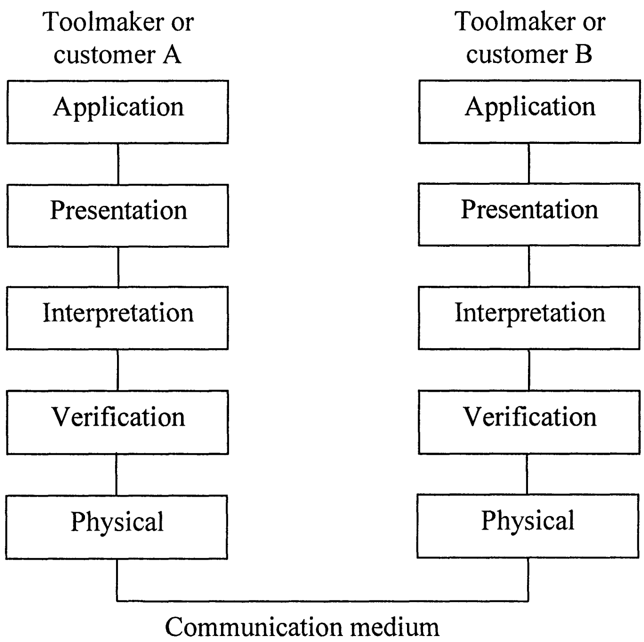

Figure 1 – The RELINK Communication Framework

The application layer describes the functions that a toolmaker needs to use the information for their work. For example, the toolmaker may use the information as a basis to design a new part, or he/she will use the information to schedule the machines for the next 24 hours. Two toolmakers, or the customer and the toolmaker must communicate at this level in order that the VE can fulfil its mission.

The presentation layer is the interface between application layer and interpretation layer. It contains the functions to convert the information to a format suitable to be used by the application that the toolmaker wants to run. For example, a toolmaker may receive a faxed drawing. Someone will perform the presentation layer function to convert this information into a computer model. There is no fundamental change of the content of the information. Communication between two communicating parties at this layer requires evaluation and perhaps, confirmation of the accuracy in the content of information being transmitted.

The interpretation layer performs the function of diverting information into relevant streams. In a communication process, there are many types of information transmitted. For example, a parcel consisting of some drawings, a project plan and a product specification is received. Different people in the company will process each of this information and hence a normal handling procedure is to divert parts of this information to different departments for processing. Communication between two communicating parties at this layer involves the identification of corresponding functional departments of the partners and gathering of information pertinent to (not necessarily exactly the information the other party desires to have) the communication parties.

The verification layer performs the function of ensuring the information transferred is actually the data that the sender wants to transmit. This includes tasks such as receipt certification, content acknowledgement, re-transmit request when errors occur, incomplete delivery handling, master copy filing, etc. In the toolmakers' VE environment, these functions will sometimes be performed by a number of parties, including outsourced entities. For communications using electronic media, this layer will probably be handled automatically.

The physical layer represents the transmission media that will be used in the communication process. The choices depend on the sophistication of technologies available to the partners in the VE.

5. AN EXAMPLE RCF SCENARIO

We attempt to illustrate the RCF concept by an example scenario. Communication scenarios can occur with toolmaker to toolmaker, or customer to toolmaker, or vice versa. The aim is to model the complete end-to-end activities in a process map, which can then be combined with other process maps to enable abstraction of functions to RCF. Note that the processes described are examples of activities that are likely to occur in this scenario. Different companies may have slightly different set of activities and work sequences. The processes are captured by software called VSMap.

The example scenario is to "design new tool from part model". A customer requests a toolmaker to design a new tool for his new part. The customer sends his part model in a CAD system to the toolmaker. The toolmaker has an alternative CAD system and will design the new tool based on product information supplied. Figure 3 shows the process map of the scenario.

The customer has already designed the product in his CAD-a system. He runs the CAD-a system and extracts the part model from the overall product model into a STEP file. The STEP file is too big to be transmitted through email so it will be sent as a CD. The customer also plots the drawings of the part model for inclusion into the information that the toolmaker can use to verify correctness of the part model. The customer also compiles supplementary product information that the toolmaker may need to design the tool. He then writes a covering letter explaining the actions required and the information packaged in this transmission. The CD, drawings, supplementary information and covering letter are packed into postpak and sent by mail.

Upon receiving the postpak the toolmaker unpacks it and verifies that the items are intact. Confirmation of receipt of postpak may be required but in this model, it is assumed that it is not a registered post. The transmitted information is divided into 2 parts: part STEP file and drawings (mainly part geometry), and product information (usage, appearance, application considerations, part weight, part size, materials, texture, etc.). The toolmaker tries to read the part geometry information into his CAD-b system. Most of the data are accepted except some critical sections, which the toolmaker has to compare with the drawings supplied and makes necessary corrections (or if the CAD-b system cannot handle such feature, an alternative CAD modelling method is applied). The outcome of this work is to produce a CAD-b model that represents the original CAD-a model. The toolmaker then takes this model together with other product information and develops a specification, which consists of the concept and geometrical formulation of the tool required to manufacture the product. This information is produced either through a thinking process or in a team working environment. When the tool is conceptualised, the tooling specification is compared with the available manufacturing processes to make the tool. Decisions will be made on process adaptation, partners' contribution, outsourcing (jobs to be done outside of the tooling VE) and other factors. The tool is finally designed in the CAD-b system and its database. The process model is overlaid with the RCF layers as shown in Figure 4.

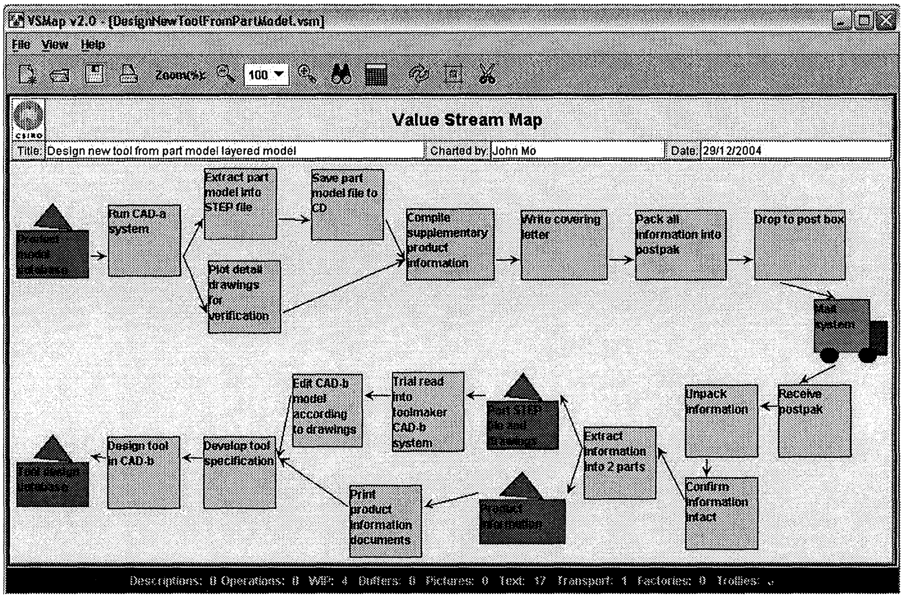

Figure 3 – Process map for exchanging CAD information

In Figure 4, activities "drop to post box", "mail system" and "receive postpak" are classified as physical layer functions. These activities serve as moving the information from one physical location to another. The content may be damaged in the activities. Traceability of where the parcel was during transmission may be included and in this case, acknowledgement through the mail system is necessary. The return path of acknowledgement is not modelled here.

The customer verifies the data to be transmitted through the activity "pack all information into postpak" while the toolmaker verifies the data received by "unpack information" and "confirm information intact". These activities are primarily to ensure that the parcel has no apparent distortion and is in its original form, as packed at the customer's location. Request for resend may be required if damage is found unrepairable.

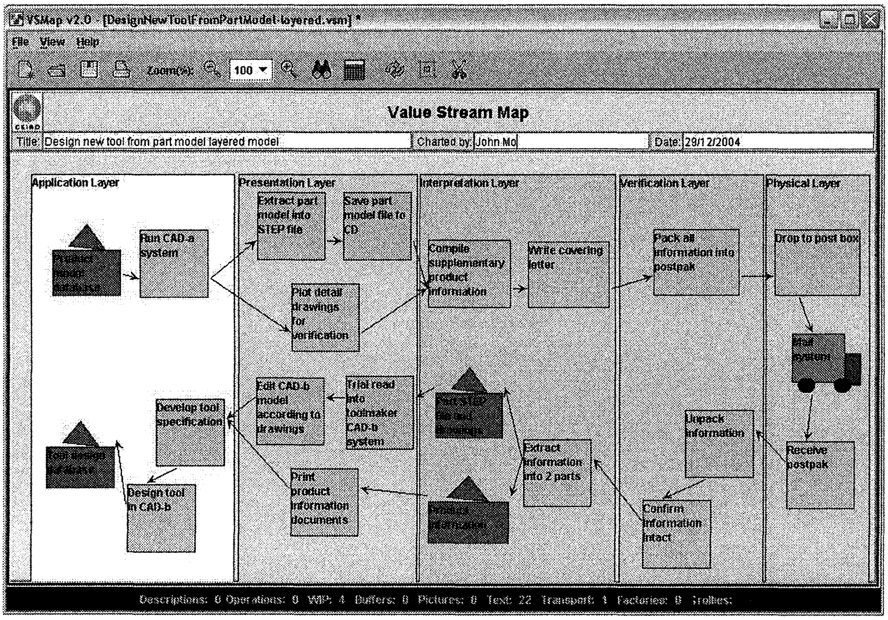

Figure 4 – Layer segmentation by RCF

The customer provides an interpretation of the information to be sent by activity "write covering letter". The letter not only provides meaning to the information but also lists the information that will be transmitted and how they are linked. In a normal transmission, some description of the product is required and such data may come from several departments (activity "compile supplementary product information"). The toolmaker's engineers interpret the customer supplied information in activity "extract information into 2 parts". The two streams of information are separated into appropriate files/directories: part STEP file and drawings, production information.

Following on the toolmaker's process, the STEP file is read into CAD-b for presenting to the engineers in 3D form. It is well known that STEP files do not usually transfer 3D model completely. Hence, an additional activity "edit CAD-b model according to drawings" is required to present the information in a form that is compatible with the same view as the customer had. Product information is normally represented conceptually and hence is printed. Back to the customer side, the customer's view of the part is extracted from the CAD-a model and presented as a STEP file generated from CAD-a system. To ensure complete presentation of the part model, a set of drawings of the part is also created to accompany the electronic STEP file.

The application layer consists of the customer accessing the CAD-a product model from his design database. At the toolmaker side, having the same view of the customer's part model (3D and product information), design of the tool can be started. The outcome of the function is a tool design that is stored in the CAD-b database.

The ICT used in this scenario are:

- **Information** – CAD systems, STEP Level 1 exchange mechanism, document repository
- **Communication** – postage, and possibly telephone confirmation

6. CONCLUSION

The RCF shows that communication within a tooling VE is a chained process. Activities that are planned according to the framework will be effective and efficient. Activities that need to break the chain can be done but the costs of communication will be significantly higher.

To develop the RCF further, studies of the existing communication processes that actually occur in the tooling industry will be vital to the success of modelling RCF and projecting how RCF migrates to describe the future scenarios.

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