An architecture for e-cooperating business agents

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***Abstract* — The task of coordinating business agents to accomplish complex goals, which could not be accomplished by any of the agents on its own, is a complex one. This paper addresses the problem of coordinating companies within a general architecture for e-cooperation. This architecture articulates the interoperation of business process over the Internet with varied degrees of security requirements. The implementation infrastructure is used to support the cooperative design and construction of production facilities (spot-welding lines, assembly lines). These are typically complex systems, which are made of several subsystems (robots, machines, cells), that are designed and built by different companies in different countries. Design and construction involves several types of companies, from OEMs to small engineering houses. With this architecture we aim at improving the otherwise time consuming task of coordinating their activities, especially when models (geometric, process, and workflow models), machine programs, documentation, etc. must be exchanged frequently and securely.**

***Index Terms* — Collaboration Systems and Technologies, Workflow Systems and Technologies, Decision Making in Business Environments**

I. Introduction

To react dynamically to changes is today's most desired property for production enterprises. There are several aspects to enterprise dynamic reconfiguration. In this paper we focus on reengineering production facilities in case of product redesign and in case of changing demand, and on optimizing the production process or removing errors that might have emerged.

The VIDOP project aim is to develop methods to combine distributed models of the components (sub-models) to build a complete model (integrated model) of the whole production facility. The final result is an infrastructure for vendor integrated decentralised modelling (IVM) which includes a communication platform enabling co-operative work with clearly defined views between the manufacturer and the suppliers to transmit securely and quickly models (geometric models, process models, workflow models), machine programs, documentation, notifications etc. The Internet allows the use of the provided models at distributed locations (manufacturer, supplier) leading to a decentralized and parallel optimization process with faster reaction to changes in product design or system errors at the manufacturer site.

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This paper is organized as follows. Section two describes an illustrative example to provide the motivation for our developments and introduces a brief description of the current practice. Section 3 presents a conceptual architecture for co-operative production planning and section 4 its prototype implementation. Section 5 presents concluding remarks and discusses future developments.

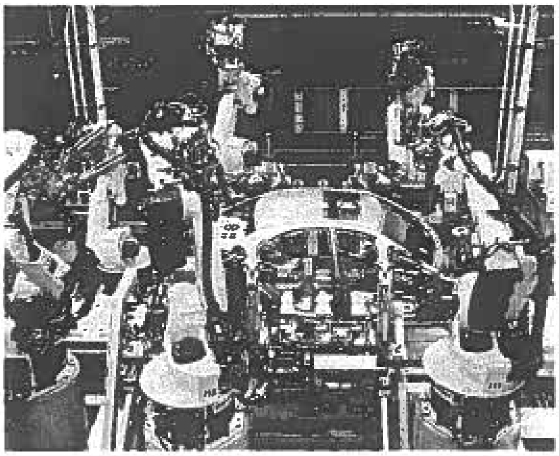

Figure 1 – Assembly cell from the body in Sindelfingen (DE)

II. Illustrative Example and Motivation

Consider the following example from the automotive industry.

An existing DC body shop in Sindelfingen (DE) has to be modified in order to be capable of delivering a new product with slightly different characteristics from the existing ones (different sunroof). The production of this product requires the modification of the actual manufacturing line. These modifications are analyzed internally by the OEM (DC). The project at hand involves reengineering of an existing line in

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order to handle new products along with the "old" ones. This project can be split into several tasks, either according to the cells (components) that need to be modified, or to the technologies involved in the process.

Usually, the OEM contacts the supplier of the existing line mostly because this supplier has all the required information (specification, models, etc.). This fact precludes the OEM from selecting a different vendor from its pool of usual "technology" suppliers (that best fit the tasks identified for this project).

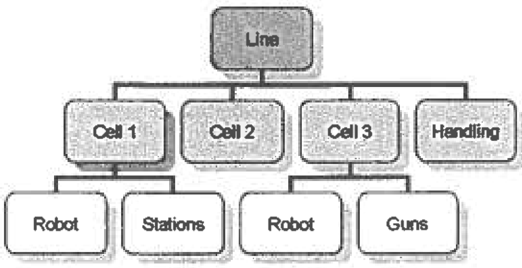

Figure 2 – Overall project structure (component view)

In our example, the OEM selects the supplier of the original line (KUKA). KUKA, acting as a turnkey supplier, then selects sub suppliers to take care of the redesign of cells 1 to 3 and of the handling system. In turn, suppliers 1 and 3 feel the need to split their task (this is their project) into subtasks. Each of the suppliers then selects from their own pool of "technology" providers the ones that best fit the tasks at hand.

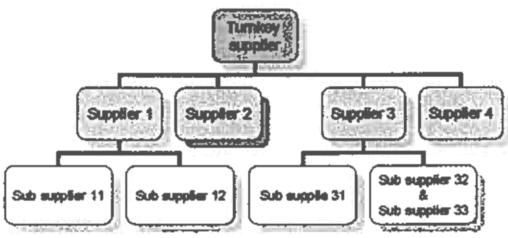

Figure 3 – Overall project structure (company view)

These temporary organizations – partnerships – only last for as long as the associated project and must be setup rather quickly.

After the partnership is defined and tasks are allocated among the involved partners, the necessary information has to be exchanged (and information flows must be defined).

Information, drawings and models are exchanged on a need-to-know basis only. In this case, the OEM sends the necessary information (cell drawings, part drawings and new part parameters) to the turnkey supplier who, in turn, sends the information about cells 1 and 2 to suppliers 1 and 2, etc. Supplier 1 filters the information he has and only sends partial models and drawings to its sub suppliers (11 and 12). In the case of sub suppliers 32 and 33 they both get the same information but maybe with different privileges.

The case of supplier 4 is special. In order to redesign the handling system for the overall line, supplier 4 needs information about the overall system (e.g. to perform material flow simulations). Supplier 4 needs information about cells 1 to 3 but not in the level of detail needed to redesign the cells. Although the "as is" information is necessary to start this task, supplier 4 also needs updated information about the changes planned to cells 1, 2, and 3.

A. Generalization

Rooted on the particularities of the example presented and on the "Phase and Role Model" (Project deliverable) a generalization of the "Co-operative Plant Production" (CPP) scenario can be developed. In this more general scenario we will have several OEMs and several technology suppliers (which can also work as sub suppliers) divided into Line Builders (suppliers of a complete line or cell, but also can work as turn key suppliers) and Engineering Houses (suppliers of partial solutions).

In a general case the OEM can subcontract a project (new line or line change) to a turnkey supplier (line builder), or to different line builders for different lines/cells (the OEM is responsible for project management), or to different line builders for different lines and different engineering houses for lines designed by OEM (the OEM is responsible for project management).

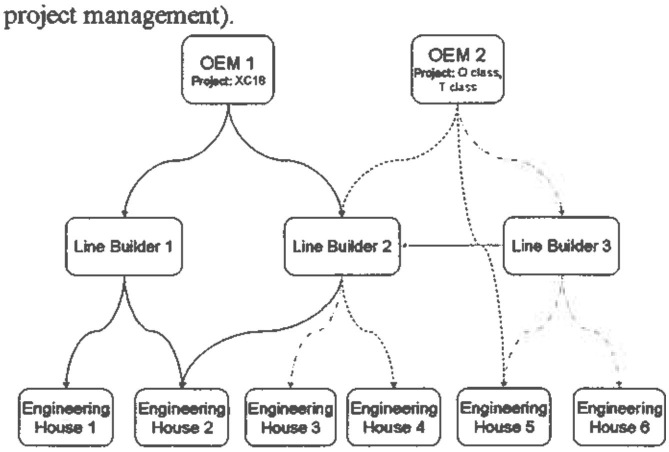

Figure 4 – Generalized Co-operative Plant Production

A Line builder can work as supplier for different OEMs and, at the same time, as turnkey supplier. A line builder can also work as sub supplier of other line builders. In turn, the line builder subcontracts work to other line builders and to engineering houses.

An engineering house can work as subcontractor of different line builders and different OEMs. It can also be the case of working as a sub supplier of the other engineering houses.

The roles and responsibilities of each of the partners in a generic project are presented in Table 1~~Table 1~~.

B. *Current Approach*

Today there is no common infrastructure to support this kind of co-operative projects. Communication flows are very well defined but information management is done on a project basis, and communication is done through dedicated lines using proprietary platforms. This makes it very difficult for small sized enterprises to collaborate with different OEMs because of the burden associated with information management, and the cost associated with the required platforms.

As a consequence, reaction time is very slow, which means that ultimately there is a longer time to market, and there is a huge possibility of redundant information exchange and inconsistent information. At the same time, the security and access control methods used are strong co-operation hinders.

III. Conceptual Architecture for CPP

A. *Organizational Concept*

Based on the generalized "Co-operative Plant Production" scenario a supporting conceptual organization can be derived. The proposed organization is based on a hierarchical recursive structure.

The OEM sets up a project, identifying a task and a partnership, (one in the case of a turnkey supplier) to several suppliers, to work on the project. In turn, each partner creates a new project based on his task (or tasks). These new tasks are either done in house or (sub) suppliers are contacted to deliver the product.

This organization structure can be defined using an object oriented approach (Figure 6) or using XML. Figure 5 represents the XML schema for the conceptual organization presented. Besides partners and tasks, the sequence of tasks, their duration and precedence relations, the companies and their role, are also defined.

B. *Methods and Rules*

In order to enhance existing co-operation in plant production, methods for the exchange of information (models or just data, etc.) and events have to be established. Some are merely administrative functions to establish and to manage co-operative work projects (defining tasks and work items), but others include user functionality for managing work and information.

Besides specific co-operative work functionality, co-operation cannot exist without trust and security. The building blocks of trustworthy co-operations are methods for secure communication and for information control.

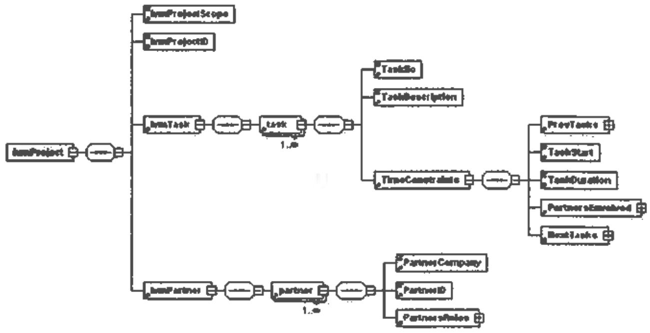

Figure 5 – CPP Schema

Co-operation enabling methods and rules can be divided in three groups:

- Co-operative work support methods.
- Workflow, work management and work sharing methods.
- Knowledge protection and security methods.

Role	Responsibilities
OEM / Turnkey supplier	Manage and control planning process for OEM project scope Integrate different sub models into complete model Planning activities and optimization of complete model Reuse of processes and resources Keep core competency and know how for manufacturing and planning Keep flexibility in selection of line builder
Line builder	Manage and control planning process for line builder project scope Provide OEM with sub process models for integrated OEM environment Integrate different sub process models of engineering houses Integrate different sub simulation models of engineering houses Reuse own standards and best practices
Engineering houses	Manage and control planning process on engineering house level Deliver to line builder / OEM the sub process models or the sub simulation models

Table 1 – Roles and Responsibilities

Co-operative work support methods include such functionalities as:

- File sharing: exchange of initial data; download; upload; update.
- Collaborative work & discussion: chat room; instant messaging; collaborative review of documents, images or models; video conferences.
- Outliner: collaborative environment for sharing ideas or organizing projects.
- Workflow definition and synchronization: task list definition; schedule definition: appointments; deliverables.
- Project management: (re)define user roles or access rights; status check.

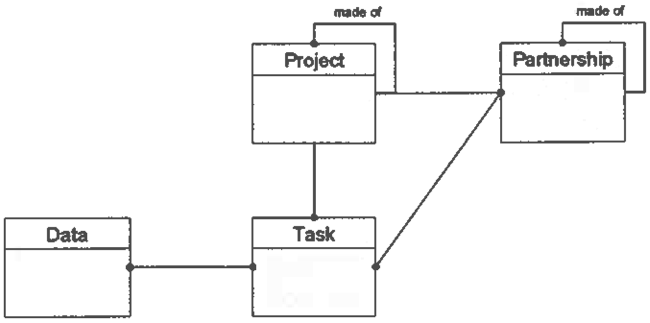

Figure 6 – Model for co-operative project

For workflow management: work management and sharing rules can be classified as workflow dependent rules. These rules define special rules dependent on the process that is running, the company organization and on the methods that are used. For a co-operation project dependant co-operation workflow controls the inter-company flow.

The knowledge protection and security methods include functionalities to:

- Control access to shared data, with role based access control and customizable views.
- Authenticate and validate users, using two factor authentication.
- Secure data transmission over insecure lines, ensuring the privacy of the data.
- Ensure messages are not altered during transmission.

C. *Inter Company Workflow*

According to the ISO 9000 [1], every organization exists to accomplish value-adding work. Work is accomplished through a network of processes. Business processes define the ways organizations add value.

The Workflow Management Coalition (WfMC) defines workflow as the complete or partial automation of business processes. A Workflow Management System is a system that is capable of defining, managing, and executing workflows.

In "Co-operative Plant Production" the network of processes spans across inter departmental and inter company boundaries. To enhance this feature, inter departmental and inter company workflows must be supported. Business processes must be combined in order to create process chains that transfer (or create) value, and since the integrated approach is not possible most of the times – process chains that span multiple organizations and workflows supported by different WMS – it is necessary to ensure workflow interoperability. Workflow interoperability is achieved when two or more workflow engines coordinate their activities in such a way that it looks like, for an external observer, a single service.

In 1994 the WfMC defined a reference model [2] that proposes an architecture for WMS. In this model five interfaces are defined, in order to insure that interoperability among workflow engines and among workflow engines and other applications is possible.

For workflow engine interoperability, and hence for business processes interoperability, the used interface is number four. Through this interface heterogeneous workflow engines (from different vendors) can exchange, transparently, work items between themselves. This way it is possible to have several workflow engines cooperating in order to deliver a single workflow service.

This interoperability is achieved through the use of standards. Currently Wf-XML [3] is in use, and it is the result of a process that started with the "Workflow Interoperability Standard" [4], jointFlow, and SWAP (Simple Workflow Access Protocol). Wf-XML is a structured, well-formed XML based messaging protocol, independent of the transport mechanism (HTTP by default, but a SOAP binding is under development). Context data can be included through XML extensions.

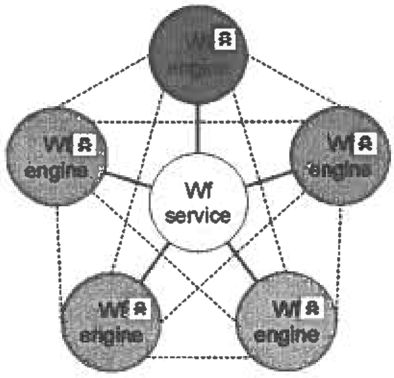

Figure 7 – Federated Workflow Architecture

IV. Architecture

The architecture for inter-company workflow management and for business processes coordination can follow a federated approach. In this approach, a central service is responsible for registering and locating processes and workflow engines. This central service can also be used to ensure workflow engine interoperability when direct interoperability is not possible.

The implementation of this architecture should use standards like XML[1], SOAP[2] and Wf-XML.

The communication between the central service, which also works as lookup and registry, and the workflow engines can be achieved through webservices [5]. When supported by both ends, Wf-XML is the default communication protocol.

A. *Prototype implementation*

The existing prototype already includes most of the security functionalities. Some basic data views and workflow functionalities are already implemented but further enhancements are on the way.

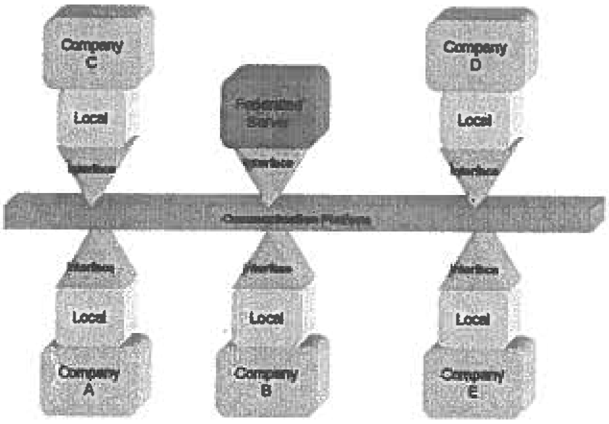

Figure 8 – Prototype Architecture

This prototype is based on a distributed architecture, with a local implementation for each participating partner and with a federated server, where the workflow service and some basic model management service are located.

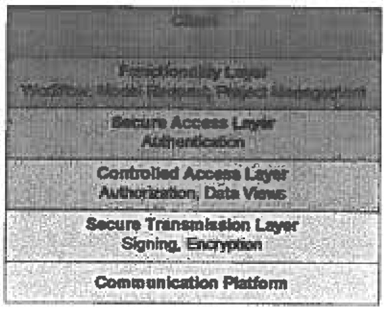

Figure 9 – Prototype Architecture

The Wf Service, located at a federated server, is a workflow engine with a webservice on top of it. This workflow engine enacts processes associated with CPP. Rules of cooperation and interaction are stored on this engine along with process templates. When a new project is created, these templates can be used as a basis to define the project structure, communication and information flows.

Each local client uses a stack of functionalities that ensure the authentication, authorization and security

The prototype was implemented in JAVA using jdk1.4 and the webservices were implemented using Axis[3] (beta2) running on top of Tomcat[4] (4.0.3) servers.

V. Conclusion and Future Work

This paper presents a general architecture for e-cooperation to address problems of enterprise collaboration and coordination. The proposed architecture defines the interactions and responsibilities among the parties involved in collaborative projects. Part of this work was developed in light of the VIDOP project, a trans-European project supported by the European Commission's GROTH Programme.

This general architecture is applied to case study drawn from the automotive industry. In this case study the architecture is mapped onto an infrastructure that is used to support the cooperative design and construction of production facilities. In this Co-operative Production Planning (CPP) project, several suppliers are involved in a project to reengineer a body shop. This application is very helpful in showing the main advantages of the architecture:

- Intra enterprise coordination and collaboration functionalities.
- Inter enterprise workflow interoperability functionalities.
- Co-operative work support methods.
- Security and knowledge protection methods.

A small description of a prototype implementation is also discussed. This prototype was built using the web technologies, like JAVA, XML, SOAP and Wf-XML.

Currently, the main focus of the work is moving onto the automatic selection (or evaluation) of potential partners and on the automatic definition of rules for co-operation (including operational rules – language and semantics – and business rules).

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[2] Simple Object Access Protocol

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