A WORKFLOW-BASED APPROACH
TO THE INTEGRATION OF ENTERPRISE NETWORKS

Diogo Ferreira, Hugo Ferreira, INESC Porto[1], Portugal
J. J. Pinto Ferreira, FEUP-DEEC / INESC Porto, Portugal
Thomas Goletz, Werner Geißler, INTERFACE, Germany
Björn Levin, Anders Holst, Daniel Gillblad, SICS, Sweden
Rui Ferraz, Francisco Lopes, Nuno M. Antunes, SMD/Pararede, Portugal
Alexandra Klen, Ricardo Rabelo, UFSC, Brazil
Kristina Ericson, Johan Karlsson, NMA, Sweden
Cândida Medon, CTC/Kyaia, Guimarães, Portugal
Domizia Lugli, Giovanni Nasi, ATECA, Italy

[1] Rua José Falcão 110 • 4050-315 Porto • Portugal
Phone: +351 222 094 323 • Fax: +351 222 008 487 • E-mail: dmf@inescn.pt

ABSTRACT

This paper presents the information system architecture conceived for the DAMASCOS (**D**yn**a**mic Forecast for **Mas**ter Production Planning with stock and capacity **co**nstraint**s**) IST-1999-11850 project[2]. The DAMASCOS project aims at closing the gap between consumer behaviour and producer by improved information flow and demand prediction in the sales and distribution networks.

KEYWORDS: Workflow, Enterprise Networks, Enterprise Integration, Interoperability.

INTRODUCTION

It is the DAMASCOS objective to design and develop an open platform providing adequate IT modules and mechanisms in order to manage Customized Supply Networks while integrating the consumer and its demands.

DAMASCOS aims at bringing supply chain management to the realm of workflow driven inter-enterprise coordination, while providing each enterprise with the appropriate forecast facilities for demand prediction and efficient stock management practices.

In fact, because each enterprise focuses on its own business processes, each supply chain participant lacks a comprehensive view on the entire chain behaviour and on its state of affairs at any given moment. Often an enterprise does not know the amount of orders or the stock level beyond tier 1 suppliers, and in most cases there isn't a realistic perception of the end-consumer demand. Therefore each participant has periods of slack followed by periods

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[2] DAMASCOS Partners: INESC Porto - project coordination (PT), INTERFACE (DE), SMD/PARAREDE (PT), SICS (SE), NMA (SE), ATECA (IT), KYAIA (PT) and UFSC (BR) in the process of joining the consortium

of frenzied activity, as stock levels throughout the supply chain fluctuate with queues of dissatisfied customers one day alternating with overstocking the next [Towill, 1999].

DAMASCOS will decrease this uncertainty by providing an inter-enterprise communication infrastructure where each enterprise can publish important events to other participants. DAMASCOS also foresees a forecast support that continually monitors market conditions, consumer demand and product advertising, being able to compute sales predictions in order to support decision making.

INTER-ENTERPRISE WORKFLOW COORDINATION

Just as a single enterprise has several interconnected business processes running concurrently, one should realize that many of those business processes extend beyond enterprise frontiers to include other participants in the supply chain. A single process may be triggered by a customer order that will reach the producer and come back through the distributor and retailer in the form of finished goods [WfMC, 1999].

This clearly suggests that supply chain management could benefit from an inter-enterprise workflow management system (inter-enterprise WfMS) that would coordinate these cross-enterprise business processes, instead of restricting workflow management to the scope of a single enterprise, which has been the current practice.

The DAMASCOS information system will be able to coordinate and supervise business processes that involve total or part of the product life cycle, from initial order to final delivery. In fact, a workflow backbone will provide the communication infrastructure and the workflow management functions that will enact and coordinate those supply chain business processes, as shown in Figure 1.
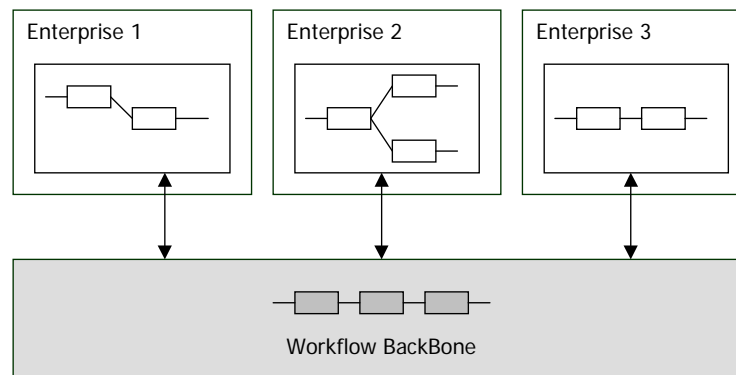
Figure 1 – Inter-Enterprise Workflow Management

Inter-enterprise business integration is therefore achieved by enabling workflow coordination, driven by events that enterprises publish on the backbone. These events will be forwarded to other supply chain partners by one of two ways:

(i)   the event is forwarded directly, from the original WfMS to the destination WfMS;

(ii)   the event is forwarded to an inter-enterprise workflow engine for processing according to an inter-enterprise workflow model.

In the first case (i), the event may trigger a new (local) Business Process on the destination WfMS. In this scenario, as a Business Process is completed in a certain enterprise (Figure

2), another one is triggered on a different supply chain partner, be it supplier (as in the case of an order) or customer (as in the case of delivery of some finished goods). Another possibility is having two local workflow models running in different enterprises, eventually being represented in a WfMS-specific manner, and requiring some king of synchronization. In this case, whenever a Business Process reaches a synchronizing activity, it publishes an event that is delivered to another WfMS waiting in a different Business Process, which also has a synchronizing point (Figure 2).
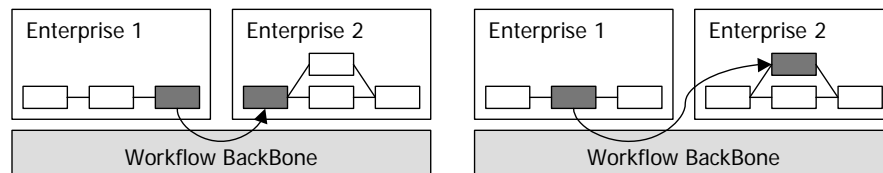
Figure 2 – Triggering vs. Synchronizing Activities

In the second case (ii), further illustrated in Figure 3, an inter-enterprise workflow model exists which dictates a precise sequence of local Business Processes. In this case, the workflow engine of the Workflow Backbone (WfBB) processes the event, determines the following business processes according to the inter-enterprise workflow model and creates and routes the appropriate events to the following supply chain partners. This means that local business processes will be triggered not by the original event that was produced on an enterprise activity but by an event that was created by the inter-enterprise workflow engine, according to an inter-enterprise workflow model [DFerreira, 1999].
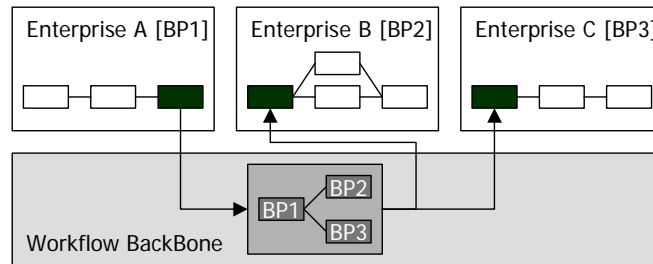
Figure 3 – Inter-Enterprise Workflow Engine

Therefore, the DAMASCOS approach concerns a new level of workflow management beyond the current interoperability trends [WfMC, 1996]. Instead of aiming at direct interoperability between different WfM systems, the main purpose is to provide a common, interceding workflow infrastructure that is able to coordinate business processes at the network level.

THE DAMASCOS SUITE

The DAMASCOS suite comprises a set of Business Functions, some of which are built on top of already available enterprise legacy systems while others are developed from scratch. This way, the DAMASCOS architecture tries to leverage existing information systems while providing at the same time the necessary functionality for the enterprise to take full advantage of the integration infrastructure [JFerreira, 2000].
The following modules compose the DAMASCOS suite:

- Sales Integrator for Supply Chain Management Application (SALSA)
- Integrated Distribution and Logistics Support System (IDLS)
- Interface to Production Order management (IPO)
- Demand Driven Decision Support System or Forecast module (D_3S_2)
- Supply Chain Smart Coordination (SC^2)
- Inter-Enterprise Workflow Backbone (WfBB)

Although a detailed description of these modules is outside the scope of this paper, it should suffice to say that each module comprises a set of Business Functions [JFerreira, 2000] that concern 6 major targets: sales (SALSA), distribution (IDLS), interface to production (IPO), forecast (D_3S_2), workflow coordination (WfBB) and conflict resolution (SC^2).
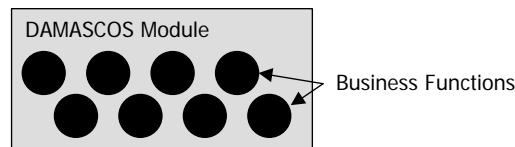

Figure 4 – Modules and Business Functions

The IPO module will play an interface role to production orders towards existing ERP system in the target enterprise. SC^2 and D_3S_2, however, are decision support modules that will be built from scratch as independent systems. SALSA and IDLS may play a broader role, comprising (a) Business Functions built on top of existing functionality, (b) Business Functions that are built in its entirety but interface or are dependent on the existing system and (c) Business Functions that constitute a stand-alone system.
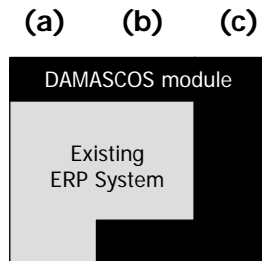

Figure 5 – Roles for Business Functions

Every DAMASCOS module, hence every Business Function, will be connected to the Workflow Backbone, therefore being able to exchange events with Business Functions belonging to a different module within the same enterprise or belonging to a module within another enterprise. The main focus is on the inter-enterprise event exchange.

INTERFACING EXISTING WFM SYSTEMS

Existing workflow management systems (WfMS) inside an enterprise will also be connected to the Workflow Backbone (WfBB) by means of a platform specific wrapper or interface layer [DFerreira, 1999], [JFerreira, 2000]. This wrapper will ensure that events concerning any particular enterprise workflow activity can be published on the WfBB. Moreover, the same layer will introduce WfBB events to the existing systems in a WfMS-specific manner.

This means that different WfM systems will become interoperable through the WfBB infrastructure, as shown in Figure 1 and discussed previously.
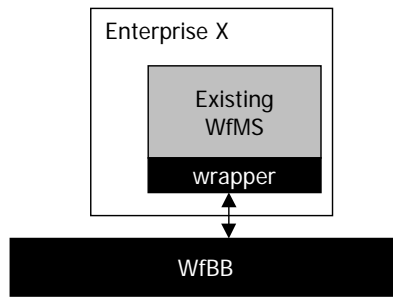

Figure 6 – Interfacing Existing WfMS

ARCHITECTURE OVERVIEW

Figure 7 presents an architecture overview, positioning each module according to its role. As discussed previously, modules are presented according to their development approach and scope within the DAMASCOS suite. SALSA and IDLS comprise a set of independent as well as interfacing Business Functions. The extent to which either role applies (from Figure 5) depends on the existing legacy systems functionality at the pilot sites, as well as the core functionality that becomes necessary to accomplish the DAMASCOS goals.
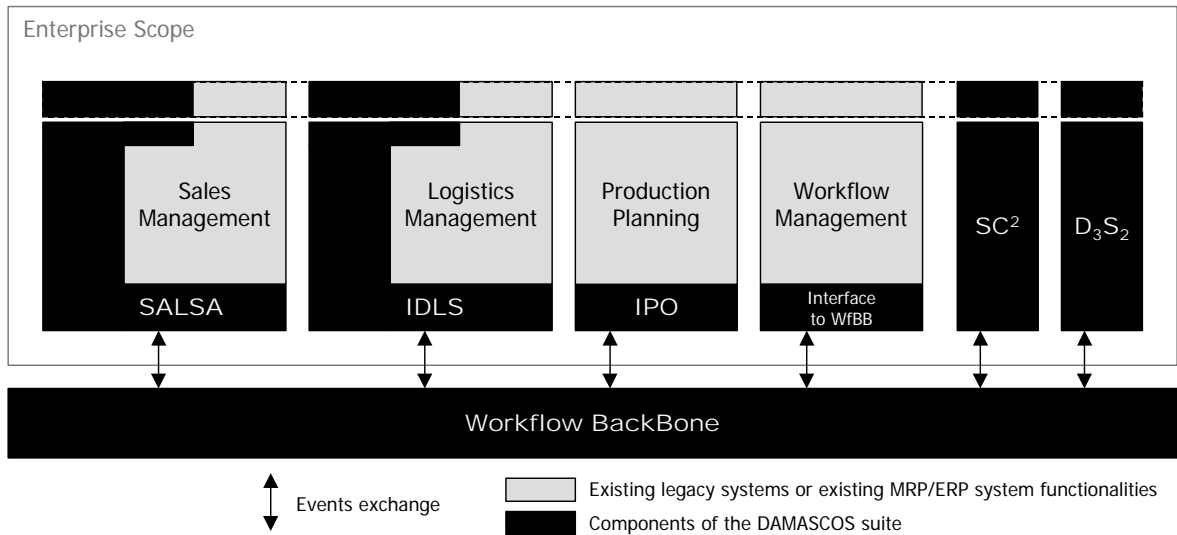

Figure 7 – Architecture Overview

The architecture is structured according to the three layers illustrated in Figure 8. Although the distinction between GUI Layer and Business Function Layer is purely conceptual, the interaction between Business Function Layer and Integration Layer (the WfBB) is a crucial issue in the overall architecture and it will be discussed in the remaining of this paper.
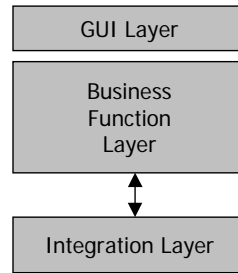
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┌─────────────────────┐
│      GUI Layer      │
├─────────────────────┤
│      Business       │
│      Function       │
│       Layer         │
└─────────────────────┘
          ↕
┌─────────────────────┐
│  Integration Layer  │
└─────────────────────┘
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Figure 8 – Architecture Layers

THE PUBLISH/SUBSCRIBE PRINCIPLE

The WfBB facilitates information or event exchange through a publish/subscribe service [HFerreira, 1999], [JFerreira, 2000]. Each DAMASCOS module (or even each Business Function) will place – publish – or collect – subscribe – events to or from the WfBB. Each event is a piece of data without particular destination that will be delivered to its subscribers. By not having a particular destination it is meant that there are no assumed recipients; events may be received by whoever subscribes them. To publish any event, a Business Function must register itself as a publisher in the WfBB; similarly, a Business Function must register itself as a subscriber in order to receive events.

By not having to specify intended recipients, the DAMASCOS approach provides one more degree of freedom for configuring and controlling inter-enterprise business processes in a model-driven fashion.

Information that is published in the WfBB becomes available to whatever purpose it may serve, be it stock management, sales forecast or workflow management, just to mention a few examples. In fact, every Business Function that subscribes a certain event is free to store it or use that information in whatever way it finds useful.

INFORMATION ACCESS THROUGH CONTEXTS

Although information published on the WfBB is common-purpose and not specifically addressed to any other Business Function, the fact that every kind of information (sales, forecast, distribution, coordination, etc.) flows within the same backbone clearly suggests that there should be some way of organizing a consistent distribution of this data.

Therefore, information will be sorted through different *contexts* [HFerreira, 1999], [JFerreira, 2000], each of which will concern a restricted set of information. By subscribing a *context*, a Business Function is granted access to all the information that is published in that *context*. For security reasons, however, subscription of certain contexts may be restricted to authorized partners.

Contexts can be further organized hierarchically, so that there is always an appropriate *context* for any Business Function or DAMASCOS module functionality, whatever specific or generic it may be. A context C1 that is hierarchically higher than a context C5 means that all events published under context C5 will still be delivered to the subscribers of context C1, besides the subscribers of C5. This can be interpreted as *context* C1 having higher authority than context C5.
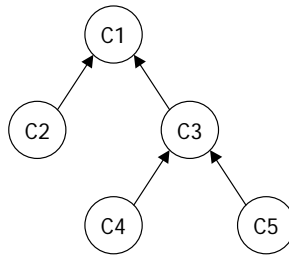
Figure 9 – Context Tree

STORING INFORMATION

Because the WfBB serves as an event exchange mechanism, each DAMASCOS module becomes responsible for handling or processing the events that the WfBB delivers. As the WfBB makes no assumptions about each dispatched event (unless it is a workflow-related event), the WfBB should not be liable for storing and retrieving them. In such a wide information system that ranges from sales to workflow, through distribution and forecast support, each module has its own way of dealing with a certain amount of information since each event may be processed by different modules with different aims. In addition, each module will probably be interested in a portion of the circulating information, hopefully a portion that it can handle. Besides, the WfBB must remain as a lightweight, distributed infrastructure, possibly crossing different platforms, without imposing requirements on the Business Function Layer.

The conclusion is that each module must be responsible for any data storage that it finds necessary or useful. The Business Function Layer should not depend on the WfBB to be a central data repository.

IMPLEMENTING EVENT EXCHANGE

To implement event exchange, two different requirements have to be met: (1) one concerns the way or how information is exchanged; (2) the other is related to the form or what information is effectively exchanged.

To meet the first requirement, some CORBA interfaces [OMG, 1998] for information publishing and subscribing in the Workflow Backbone will be specified, as illustrated in Figure 10 [JFerreira, 2000]. While the WfBB implements an "outgoing interface" for event publishing, it is the DAMASCOS module Business Function responsibility to implement the "delivering interface" in order to be able to receive events [HFerreira, 1999].

To meet the second requirement, XML [W3C, 1998] shall be used to thoroughly characterize the exchanged information [DFerreira, 1999]: each event will be described by an XML document. Whenever an event is issued, a XML stream is assembled and published in the WfBB. In the receiving end, the XML stream is parsed and processed so as to collect the intended information. Each XML stream shall obey to a Document Type Definition (DTD) that will be developed taking into account the business functions integration requirements. Translation between system-specific data and XML, and the other way around, must be assured by interfacing business functions.

The CORBA interfaces shall then comprise only handful of methods that provide complete support to the exchange of XML streams.
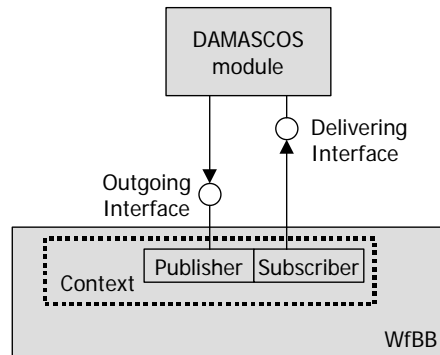

Figure 10 – CORBA Interfaces

CONCLUSION

This paper described the information system architecture of DAMASCOS and how it meets the requirements for a workflow-driven approach to supply chain management. From inter-enterprise business processes to business function integration, we have described an approach that brings workflow management to an inter-enterprise level, beyond current workflow interoperability trends.

REFERENCES

[DFerreira, 1999] Diogo Ferreira, Hugo Ferreira, J. J. Pinto Ferreira "Requirements for a Component-Based Enterprise Integration Infrastructure", INESC Porto-UESP Internal Report, September 1999

[HFerreira, 1999] Hugo Ferreira, Diogo Ferreira, J.J. Pinto Ferreira: "Workflow Backbone: Uma Infra-Estrutura para Implementar um Sistema de Workflow Distribuído", INESC Porto-UESP Internal Report (IC-PME-PRONEGI-01), November 1999

[JFerreira, 2000] J.J. Pinto Ferreira, Diogo Ferreira, Hugo Ferreira: "The DAMASCOS System Architecture – DAMASCOS Deliverable 3.3", INESC Porto-UESP Internal Report (IST-11850-02), February 2000

[OMG, 1998] Object Management Group, *The Common Object Request Broker: Architecture and Specification*, Revision 2.2, February 1998, http://www.omg.org

[Towill, 1999] Denis R. Towill, Peter McCullen, *The Impact of Agile Manufacturing on Supply Chain Dynamics*, International Journal of Logistics Management, Vol. 10, No. 1, 1999

[WfMC, 1996] Workflow Management Coalition, *Interoperability Abstract Specification*, WFMC-TC-1012, October 1996, http://www.wfmc.org

[WfMC, 1999] Workflow Management Coalition, *Workflow Interoperability – Enabling E-Commerce*, WfMC White Paper, April 1999, http://www.wfmc.org

[W3C, 1998] World Wide Web Consortium, *Extensible Markup Language (XML) 1.0*, http://www.w3.org/TR/1998/REC-xml-19980210, 1998