IT INFRASTRUCTURE FOR SUPPLY CHAIN MANAGEMENT IN COMPANY NETWORKS WITH SMALL AND MEDIUM-SIZED ENTERPRISE

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Key words: Internet Services, Supply Chain Management, IT Infrastructure, Security.

Abstract: The current trend of extending operations management beyond the company's wall focuses on the integration of suppliers and consumers into a single information network. The objective is to optimize costs and opportunities for everyone involved. However, small-sized enterprises can rarely carry the high acquisition and introduction costs of hardware and software. This reduces the attractiveness of the small-sized enterprise as partner in a logistics and a production network. This article presents a lean IT infrastructure that targets small-sized enterprises. It allows flexible and configurable integration with the Internet, ERP systems and the secure communication of supply chain management data.

1 INTRODUCTION

Supply chain management (SCM) helps companies in controlling the flow of information and goods within their network of suppliers and customers by providing a full view on what happens in the network (Hieber, 2002). The ubiquitousty of the Internet has shifted the focus from the aspiration to make the companies own operations run smoothly towards optimizing the configuration, cooperation and collaboration of a companies' suppliers and customers. Not companies, but supply chains compete against each other. However, companies are conservative in providing data to outsiders of the company. Worse, SCM software regardless whether its functionality supports planning or execution relies for its accuracy upon access to complete and up-to-date information from all the supply chain's ERP systems. This requires a fast, flexible and secure mechanism to exchange SCM data over the Internet.

The article introduces an IT infrastructure that allows flexible and secure integration with the Internet and ERP systems and communication of data with customers and suppliers. The work presented here has been carried out in the context of ERP integration in company networks that include small and medium-sized enterprises (SME).

The remainder of the article is structured as follows: The motivation of this work is presented in Section 2. Section 3 discusses the architecture of the IT infrastructure and its implementation issues. Section 4 concludes the article with a brief talk about our future work.

2 MOTIVATION

Until recently SCM has focused on advanced planning and scheduling (APS). APS is demanding regarding various aspects. It relies on a large amount of data from all partners of a supply chain as well as on the high quality of the data provided. Only consortia

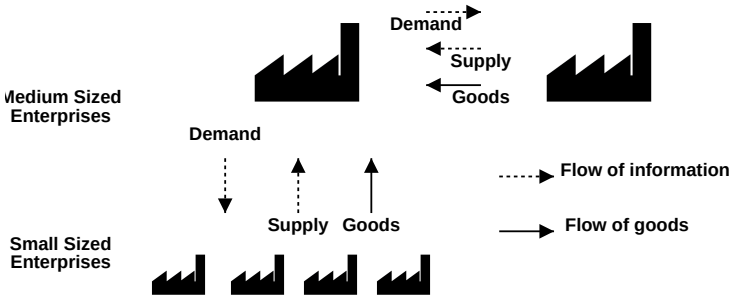

Figure 1: Small and medium enterprise logistics and production network.

of companies' legally dependent from each other can meet this demand for data and afford costly APS software solutions (Schoensleben, 2000). However, most company networks include SME - especially at tier-three and higher. To integrate them in a SCM solution, it takes a lean IT infrastructure. Such an infrastructure has to take into account the following requirements:

- *Small and Medium Enterprises*: Current Off-the-shelf solutions place high demands on the IT infrastructure with respect to hardware and software acquisition costs and human resources. In particular SME are generally not able to fulfill such requirements and to carry the high acquisition and introduction costs of the software. This reduces the attractiveness of the SME as partner in a logistics and a production network and makes integration a technical challenge. The situation arises when one party involved in the supply chain has ERP and SCM software systems and the other party involved has not (Figure 1). However, the party having ERP and SCM software systems tends integrating its suppliers into its supply chain.
- *Changing Supplier*: In industries with a high fluctuation of demand, the set of company suppliers does change frequently. Establishing the exchange of SCM data and its integration into the own supply chain requires a fast and lean solution.
- *Control*: Controlling a supply chain extends beyond the company's walls. Companies however require total control and monitoring of incoming and outgoing data. The presented infrastructure allows defining how often and at which time data is published and integrated. This scenario is typical for situations where the two parties involved have ERP and SCM software but are reluctant to grant each other access to their systems (Figure 1).
- *Security*: Security is an essential requirement of the data transfer between the parties involved in the SCM network. Security is a prerequisite to establish a network of trust between supplier and consumer.
- *Flexibility*: Flexibility of the IT infrastructure is needed to support fast-changing business processes, production environments and requirements from the ERP and SCM system. The presented infrastructure has been built to be highly configurable to adapt dynamically to changing environments and requirements. It has been built on a workflow model using components, which can be visually assembled and easily deployed.

The presented IT infrastructure takes into account the SME environment by relying on the combination of available low-cost technology. It is designed independently from any specific ERP or SCM systems. It controls the access and integration of data using the Internet with a strict security policy.

3 HIGH-LEVEL ARCHITECTURE

The IT infrastructure is designed to handle two information flows:

1. *Import SCM Data*: SCM data is sent from the small sized supplier to the medium sized enterprise. The small supplier uploads data such as expected market volume of goods it supplies. The data's format is agreed between the two enterprises. It is processed and verified semi-automatically by the medium-sized enterprise.
2. *Export SCM Data*: SCM data is viewed, searched, and modified online or offline by the supplier. The small sized enterprise downloads current and historical data such as expected market volume of products it supplies from the medium enterprise's perspective. The medium enterprise may choose to present the data in web-based form or as documents for download.

The possibility to view and exchange up-to-date data is essential for successful SCM. The IT infrastructure consists of the following elements (Figure 2):

- *Client*: The client may be an Internet browser in a small sized enterprise, which supplies goods to

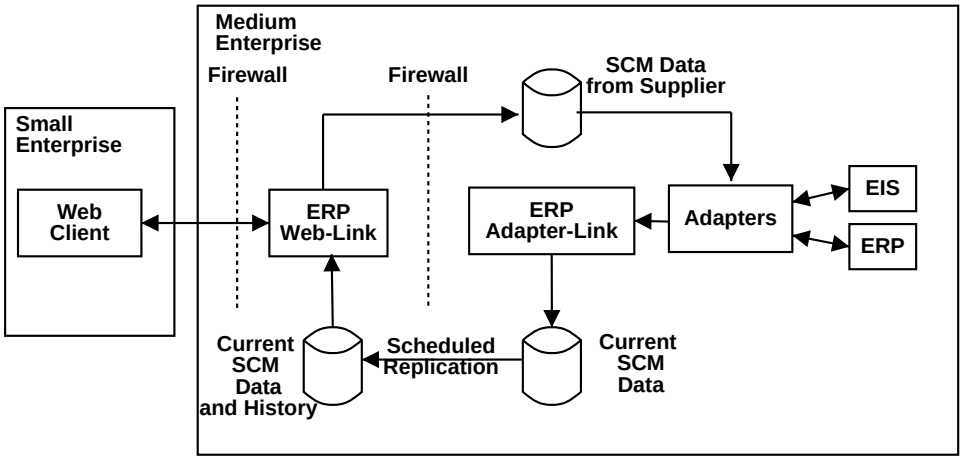

Figure 2: High-level architecture of IT infrastructure for small and medium-sized enterprises.

a medium sized enterprise that runs the ERP and SCM software systems. The supplier has little financial resources that prevent it from acquiring ERP software.

- *ERP Web-Link*: The ERP Web-Link processes securely incoming and outgoing SCM data. It resides inside the medium enterprise's demilitarized zone and is disconnected from the enterprise's ERP System. The ERP Web-Link retrieves SCM data from a data store containing current as well as historical SCM data. This data store's content is replicated data provided by the ERP Adapter-Link. Data that is uploaded by suppliers is stored in a second independent data store, which will be used by users and other applications. The data is checked and verified before further processing (e.g., import into ERP or EIS systems) takes place.
- *ERP Adapter-Link*: The ERP Adapter-Link is a configurable application that exports SCM data from various EIS and ERP systems using adapters. The data is stored temporarily in a separate data store containing the current SCM data. The ERP Adapter-Link allows defining what data has to be exported, when the export should be carried out (i.e. time, interval), and which supplier the data is intended for. The configuration is created by users in a simple and flexible way. It is used to automate the export process with a scheduler.
- *Data Integration*: Uploaded data is never directly imported into the ERP system. Upon successful verification, a human operator of the medium sized enterprise controls the import of SCM data into the ERP system.
- *EIS / ERP*: EIS and ERP systems of various types present the data source for the ERP Adapter-Link. They are accessed via EIS and ERP specific adapters.

3.1 ERP Adapter-Link

The ERP Adapter Link achieves integration of ERP and EIS systems through a layer of indirection. Instead of accessing the ERP system of a business partner directly, suppliers are only granted access to a subset of data that has been selected for them by the data provider. The data provider exports specific data, relevant to a supplier, into an ERP independent data store. That gives data providers total control and assurance that data integrity is not put at risk by their integration solution. The ERP Adapter-Link consists of two elements that are ERP specific (configuration, export) and a general purpose scheduler that automates the export process (Figure 3). The scheduler triggers the export of data and passes a configuration file - created by the configuration element of the ERP Adapter-Link - to the exporting process. The configuration describes what data needs to be exported.

Configuration The configuration process allows for graphical definition of what data is to be exported. The configuration element contains parts that are ERP specific since every ERP system provides a different API for applications to interact with.

The configuration is built in a step-by-step process (each step contributes a part of the entire configuration). Each step requires the previous step to be successfully completed. Thus the software guides the user through the configuration process:

1. *General configuration information*: This information specifies the addressee of the exported data, where the configuration data is to be saved, and where the results of the export are to be stored.

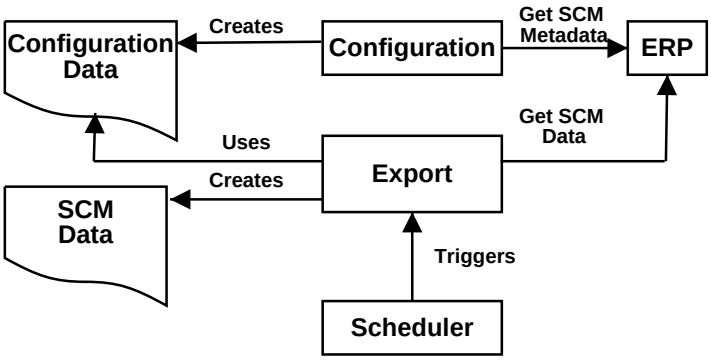

Figure 3: ERP Adapter-Link.

2. *ERP specific information*: This information specifies the data source within the specific ERP system (e.g. name of stored procedure, BAPI name, etc.). Based on the information the ERP Adapter-Link builds queries, which retrieve metadata of the particular data source from the ERP system. Eventually the metadata defines the look of the next step's graphical presentation: (a) If the data source requires input data, the user is presented input fields to enter required input data. (b) In cases where the data source produces an entire set of data, the user should be presented checkboxes to choose which elements of the set she is interested in.

An import requirement for the configuration element is ease of use. Any employee with certain knowledge of the data stored in the ERP system should be capable of using the application. Only through ease of use the necessary acceptance of the IT infrastructure and integration solution can be achieved.

Export of data The export process retrieves the data from the ERP system. The ERP specific export component connects to the ERP system and builds a valid request containing all input parameters from the configuration. After the call has been successfully executed the specified output is unmarshalled and serialized.

Scheduling The scheduler runs predefined tasks in certain intervals. The idea of yet another scheduler may seem a bit irritating at the beginning. However, it was the intention to provide users with a complete out-of-the-box solution to run periodic exports. It is not a satisfying solution if users have to write batch or shell scripts that are executed by an often OS-dependent scheduler. Two concrete tasks have been implemented so far:

1. A task which runs a specific export data process.
2. A replication task that copies data from one data store to another. In this case, a data store is a file containing SCM data. The task adds a timestamp to each data store for archival reason. This task is used to copy data from the data store of the ERP Adapter-Link, which contains only current up-to-date data, to the ERP Web-Link's data store.

3.1.1 Implementation

On a conceptual level there are several states the configuration process will pass on a time line. Each state is normally represented by a dynamic form that asks for user input. The relation between the individual states is accomplished by a bus architecture interconnecting the states. It is implemented as a mediator (Gamma et al., 1995) (Figure 4). The mediator provides inter-state communication. Thus it handles the activation and passivation of all states and their corresponding user interfaces. The use of the mediator design pattern results in a more cohesive implementation of the logic and a decreased coupling between user interface objects because the logic is centralized in one object.

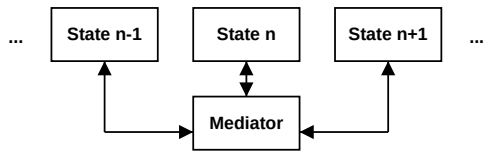

Figure 4: Encapsulation of configuration states using a mediator.

Dynamic creation of a user interface becomes crucial because the user interface in state n depends on the condition of state $n-1$. In an SAP context this results in the creation of forms for all import, export, and table parameters in state n based on a RFM (Remote Function Module, e.g. BAPI) chosen in state $n-1$. Creation of the dynamic user interface is delegated to a toolkit that employs metadata exposed by the corresponding RFM to dynamically

add labels, checkboxes, and text fields to a form. The toolkit requests a connection to SAP from a set of connection from the Managed Connection Architecture. It then retrieves all available metadata for a specific RFM. A loop through all input parameters results in a form that contains a number of label/text field combinations. For export and table parameters separate forms with label/checkbox combinations are built. The toolkit is also responsible to assemble each individual form. Finally, the configuration process employs a visitor (Gamma et al., 1995) that visits all states to assemble the configuration file.

The Managed Connection Architecture The Managed Connection Architecture (MCA) is responsible for establishing, holding, pooling, and destroying connections to remote systems. It resembles in many ways the architecture used by JCA (SUN, 2002).

For clients using the MCA (configuration, export) it exposes a connection factory which is responsible for the creation of connections to specific ERP systems. The factory delegates this task to an ERP specific connection manager. It is up to the connection manager how various aspects of connection management (i.e. pooling, exception handling) are handled. It wraps a physical connection into a handle object which is returned to the connection factory. The connection factory in return passes the reference to the requesting client.

The main benefit of the MCA is a centralized connection management. All work is carried out in a transparent manner and all clients reference the same connection factory.

Java Connector Architecture and SAP Java Connector The SAP Java Connector (JCo) bridges Java applications and SAP R3 systems (Fewster, 2001). Internally it is built upon the SAP C library to build RFCs (Remote Function Calls). JCo has been used in the configuration and export application. The J2EE Connector Architecture (JCA) is a SUN specification for the integration of Enterprise Information Systems (EIS) into a J2EE environment. JCA defines a standard interface between a J2EE application server and EISs. All EIS vendors can cover a huge market (J2EE) by providing only one single connector for their product. JCo is approved and exists already in a second release (V2.x). We choose to use JCo, firstly because it is easy to install and use and secondly, because SAP does not yet provide a production proofed JCA connector.

3.2 ERP Web-Link

The ERP Web-Link is the system that presents the interface to the Internet. It consists of a set of processes that let small enterprise suppliers visualize, modify, create, search, download and upload supplier specific SCM data (Figure 5). Its data source is the data store to which the ERP Adapter-Link replicates SCM data on a regular basis. It contains current and historical data. It stores modified and uploaded SCM data in a separate data store that is used by third party applications and users to further process the supplier's data. The ERP Web-Link consists of the following functionalities:

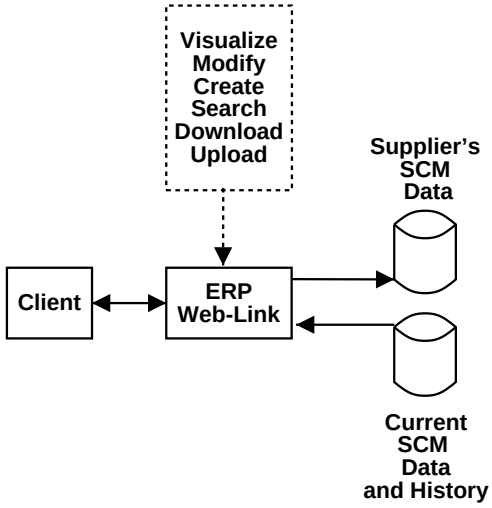

Figure 5: ERP Web-Link.

- *Searching*: The supplier must be able to find specific documents in the data store of the Web-Link. The documents contain current and historical SCM data relevant to the business relations between the small sized supplier and the medium sized enterprise that integrates the supplier's data in its supply chain. The data stems from various sources and is transformed into a XML-based data structure. The XML-based data structure applies the composite principle that allows the definition of part-whole hierarchies.
- *Presentation*: The SCM data is presented in a web-based form and as a downloadable Excel Sheet. The presentation is a two stage process: (a) The first step transforms the SCM data provided by the ERP Adapter-Link into the common XML-based data structure. (b) The second step transforms the data into one of the two presentation formats.
- *Modification*: The ERP Web-Link allows online modification and editing of the supplier's SCM

data. To get an editable view of the SCM data the presented data is transformed into an editable form.

- *Creating, Downloading, and Uploading*: The supplier submits new SCM data to the ERP Web-Link. It exports the data into an intermediate data store from where third party applications or users retrieve the data for further processing. SCM data can be uploaded and downloaded in form of a document such as an Excel document. The format is agreed between the small and the medium sized enterprise.

3.2.1 ERP Web-Link Architecture

The ERP Web-Link allows the construction of its set of processes using component assembly mechanisms. This mechanism leverages the building of processes and data-based workflow systems, which are flexible, extensible and evolutionary in the sense of rapid integration of changing requirements (Sharp, 1992). The architecture of the ERP Web-Link employs an event-driven model (Szyperski, 1998) and uses connection-oriented programming (Hofmeister et al., 1999). It can be mapped onto conceptual software architecture models. The concept of software architecture consists of three abstract building blocks (Perry and Wolf, 1992; Shaw and David, 1996) (Figure 6)

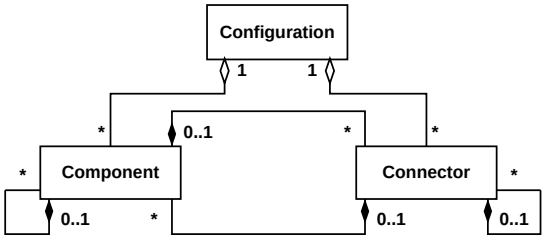

Figure 6: Meta-model of conceptual architecture view. Adapted from (Shaw and David, 1996).

Component. Components are either processing elements or data elements:

- **Processing Elements.** The processing elements consist of Java Beans (SUN, 2002). Conceptually, there are three classes of processing elements: process element, function element, and activity element (Figure 7). Each type of element is employed on a different layer of the architectural configuration, which is named after the element. The process layer is composed of a set of function elements that form the function layer. It handles the user interaction and represents the overall process logic, such as search SCM data or download SCM data. The function layer provides a specific functionality to the process layer, such as document processing and transformation functions. The activity layer provides basic functionality to the other two layers, such as document loading, transformation capabilities and logging.

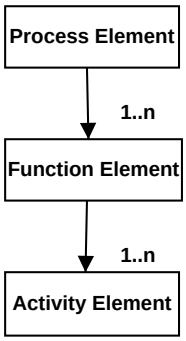

Figure 7: processing elements layers.

- **Data Element.** Each processing element assumes a common data element. In its structure, the data elements resemble the SOAP envelope (W3C, 2001). It consists of a data envelope containing a data header and data information sections and encloses the data body. The data element represents the XML-based form of the SCM data.

Connector. A connector acts as data channel between two components. The connector between two processing elements is established and generated dynamically during assembly-time. It is based on dynamic proxy classes.

Configuration. The configuration is the structural organization of the components and connectors. It provides a high-level overview of the architecture of the ERP Web-Link. The configuration is composed visually in a tree structure (Figure 7). The root of the configuration tree represents the process layer containing a single process element. This element and its child elements are deployed and implemented using Java Servlet or EJB technology (Roman et al., 2002). The leafs of the configuration tree are activity elements. Activity elements are the basis building blocks of the ERP Web-Link. Each inner node serves mainly to direct and check the data and control flow. Inner nodes belong to the class of function elements.

3.3 Security

To ensure secure exchange of SCM data secure socket layer (SSL) technology is used to protect the web communication. It is applied on the process layer of the ERP Web-Link configuration tree. SSL security provides data encryption, server authentication, data

integrity and client authentication (Netscape, 2000). Authorization can be applied on the function layer of the ERP Web-Link configuration. This might be useful in cases where only selected users are allowed to execute specific functionality. For example, all users are granted access to SCM data, but only authorized users are allowed to modify and to submit data.

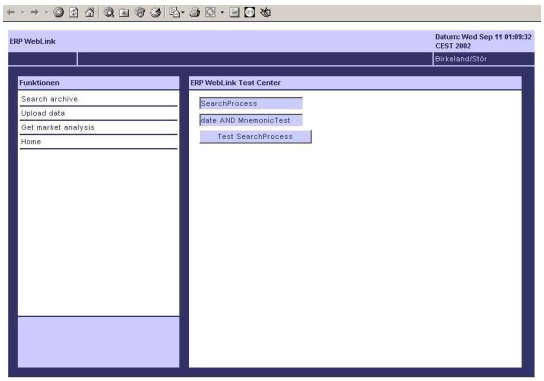

Figure 8: ERP Web-Link: HTML user interface.

3.4 Implementation

The set of processes forming the ERP Web-Link has been composed using the SUN Bean Builder. The Bean Builder has been modified to allow deploying the ERP Web-Link as Servlets onto a Web Server, or optionally as EJBs.

XSLT (W3C, 1999) has been used to transform SCM data, which are present in XML format, into a presentation format, such as HTML. Figure 8 shows a screen shot of the HTML user interface of the search functionality of the ERP Web-Link.

We implemented search functionality with the help of the Jakarta Lucene Query Processor (Apache Jakarta Project, 2000). Jakarta Lucene is a query processor that provides a high performance search engine that works on text. It has been a suitable technology for searching XML-based SCM data. Figure 9 shows the composition of the search functionality in the SUN Bean Builder.

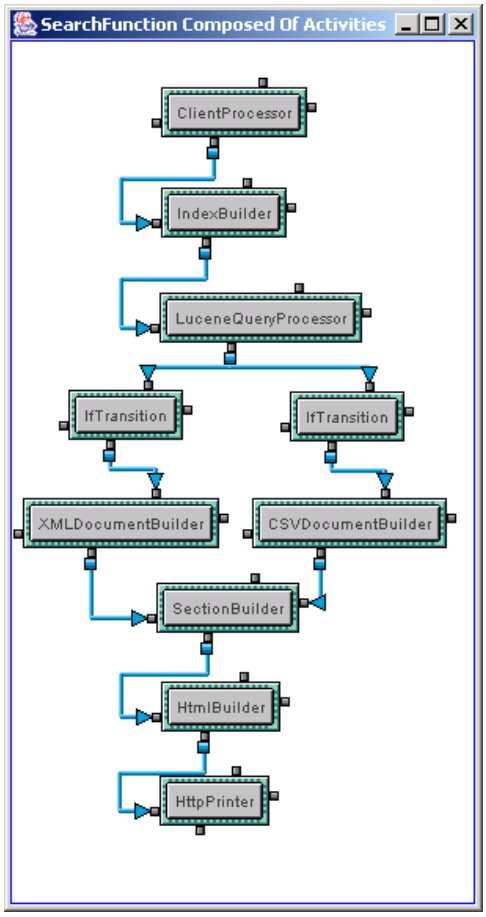

Figure 9: Simple configuration of the search functionality composed in the SUN Bean Builder.

4 CONCLUSION

In this article we have presented a lean and low cost IT infrastructure for the integration of ERP systems with the Internet and the communication of supply chain data between suppliers and consumers. The work aims at providing a solution to small and medium-sized enterprises that cannot respond to the hardware, software acquisition costs and human resources required by current off-the-shelf solutions. We showed that the combination of open source technology allows the construction and composition of flexible, extensible and evolutionary software solutions.

Future work will focus on extending the functionality of the ERP Web-Link. We will continue working on analyzing the configuration in the ERP Adapter-Link to further ease this process. Simplicity and ease of use are important objectives in order to encourage the use of the presented technology.

5 ACKNOWLEDGMENTS

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