VALUE ADDED WEB SERVICES FOR INDUSTRIAL OPERATIONS AND MAINTENANCE

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Abstract: Efficient information management is needed at industrial manufacturing plants that compete in the present demanding business environment. Requirements to enhance operation and maintenance (O&M) information management emerge from problems within internal information flows of a plant, supporting the networked organization of O&M, and accomplishing the new demand-driven business model. O&M information management of an industrial process plant is here proposed to be enhanced by value added web services. A service framework will work as a supporting architectural context for the value added services. Information from existing systems, such as automation, maintenance, production control, and condition monitoring systems, is analyzed, refined and used in control activities by the services.

1 INTRODUCTION

From the phases of the life cycle of an industrial manufacturing plant, the operational phase is the longest and during it the plant is expected to pay back all costs of its life time and produce profit for its owner. Changing operating environment, squeezing global markets, and decreasing profit margins, among others, place challenges in fulfilling these expectations. To remain competitive, manufacturers need to adopt advanced and integrated operation and maintenance (O&M) of a plant.

O&M means activities that are performed during operational phase of a plant. The primary goal of O&M is to secure the undisturbed operation of a production plant and to make manufacturing as profitable as possible. Critical aspect in reaching this goal is information management and application of modern information technology. Manufacturers should be able to fully utilize the information in O&M information systems. Achieving this requires the ability to easily integrate these systems.

An effort called OpenO&M For Manufacturing Joint Work Group has been recently formed by three non-profit organizations, MIMOSA, the OPC Foundation, and the Instrumentation and Automation Society (ISA) SP95 committee to harmonize the various existing standards from these organizations (OpenO&M, 2004). The goal of the joint effort is to provide the standards and technology that form an interoperable framework for exchange of O&M information.

In addition to standards, technologies which enable integration functionalities are also needed. Web services provide standard means for interoperating between heterogeneous information systems utilizing different platforms, programming languages, and component models (Booth *et al.*, 2004).

2 O&M INFORMATION MANAGEMENT

In this chapter, current state and problems of O&M information management are discussed. From these, requirements for integration are derived. Discussion is based both on literature and a set of production plant interviews (Viinikkala, Jaakkola, 2004) that were conducted in order to examine O&M information management at Finnish industrial plants.

2.1 Information systems

Figure 1 depicts the information systems used on different levels of manufacturing organization, which are defined in (ISA SP95, 2004). The information systems function as repositories of various kind of information about the past and present state of the production plant. Information

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concerning the process, its state, control signals and measurements, is collected and stored by the distributed control system (Paunonen, 1997).

Maintenance activities are supported by Computerized Maintenance Management Systems (CMMS), which are basically database systems that usually contain information about maintenance work orders, equipment maintenance history, and preventive maintenance schedules among other things related to maintenance.

Charasteristic for the information systems at industrial plants, though alike in their database centricity, is that they are built with different techniques on different software platforms and are not thus inherently interoperable.

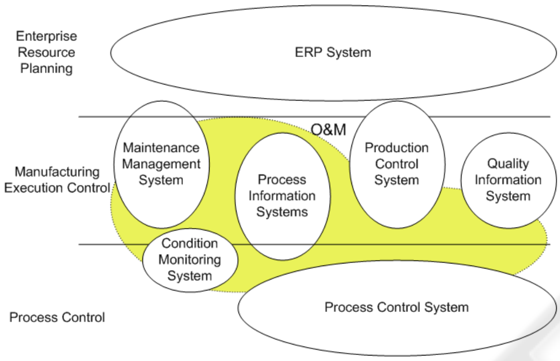

Figure 1: O&M information systems. Modified from (ISA SP95, 2004) and (Viinikkala, Jaakkola, 2004)

2.2 Integration of operations

Production and maintenance are not separate, but related and parallel activities. The production process requires energy, materials, and work force as its primary inputs, but also production capability as its secondary input. This is produced by maintenance. On the other hand, the secondary output of the production process is the need for maintenance which is the input for maintenance (Jonsson, 1999). Ideally, related operations should be supported by information systems.

Many information systems exist at a plant, but they are rarely considered as a whole. A given system serves the needs of a particular activity only – not the O&M of the whole plant. The starting point for integration is poor in this sense, because legacy systems have not been designed to support integration.

Also, because of the information fragmentation and due to lack of standard interfaces, finding the relevant information to support O&M decision making from various information systems is hard. For example, maintenance history knowledge may be fragmented to several information systems (Mäki, 2000).

Some custom links that are typically not based on any standard interface have been developed in order to integrate a system with another system. By using this kind of point-to-point approach, information can be exchanged between two information systems. However, each system has its own data model, which has to be made compatible with each other. Thus, the point-to-point approach based on non-standard interfaces is laborious and inefficient and thus expensive.

Information that is read from a system or a set of systems could be analyzed by some intelligent entity. Based on the result of the analysis, information could be written into some other system, thus accomplishing automatic transactions between participating systems. This kind of intelligent co-operation, orchestrated by intelligent entities, does not exist at industrial plants yet.

Majority of information flows between systems are currently accomplished manually by means of a human mediator. This situation causes latencies in information flows between systems. Human effort is required even in routine information exchanges between information systems.

In order to overcome these problems, integration of the existing systems is required. Going further, information is required to be accessed by using standard interfaces, which the information systems are required to provide. Further, information is required to be processed by services that use the standard interfaces to access the information. Such services are required to contain business logic or intelligence to accomplish the information integration or to implement the required co-operation among systems.

2.3 Networked O&M

The responsibility for maintaining the production equipment is transferring from proprietary organizations of the production plant to dedicated service providers (Viitamo, 2000). The traditional arrangement, especially in the heavy process industry, has been organizing maintenance with plant maintenance personnel.

Responsibility for equipment effectiveness requires the awareness of the equipment condition and production state. Thus constant information exchange between the external service provider and the production plant is needed. The current information systems and the integration techniques that are used in operation and maintenance do not adequately respond to this need. The collaborative efforts of O&M rely on the collaboration of human experts and the plant operators.

Ideally in case of a problem, the required knowledge and information to solve it is available immediately, and the necessary notifications to all relevant directions are sent automatically. Means to also external interest groups to access O&M information in a controlled way are needed. The way of accessing information should be the same for both internal usage and external interest groups. Currently, the friction in operations that require the attention of several people leads to latencies in various stages of the situation, which causes unnecessary loss of equipment availability.

To reach the ideal performance in collaborative O&M, the operations must make use of new kinds of information processing solutions that support them in a holistic manner. These solutions must not override the existing information systems infrastructure but include them as an essential sources and storages of data.

2.4 Visibility into operations

The business model that the manufacturers prefer has changed from a model, in which products are made to stock, to a model, in which production is entirely based on orders and customer needs. Currently, supply chains are becoming faster and more integrated with support of e-business.

Demand-driven business model cannot be accomplished without information from lower automation levels at plants. In enterprise resource planning-level, which can be seen from figure 1, plans, that satisfy customer needs, are designed. These plans can not be accurately made without knowledge about O&M operations and status.

Forrester recently published results from a survey of the top 50 global manufacturing executives, in which they were asked to answer the question: “What are your biggest problems with global manufacturing?” The biggest problem the survey indicated was “poor visibility into plant operations” (38%). (Forrester, 2000) Thus, the biggest concern at the enterprise resource planning level is that managers and other personnel are not seeing the right information to make the best possible decisions on how to run the plant. As supply chains are becoming more efficient, the plant and its operations are becoming the bottleneck of the whole value chain. Current systems, as they are, are inadequate in providing the required visibility into operations. Also this viewpoint emphasizes the integration requirement.

2.5 Architectural requirements

The general integration requirement discussed in previous sections implies further requirements for the integration architecture.

The integration architecture should enable extending the existing information systems, which will continue to serve the plant level functions. The extension functionality must be generic so that it can be reasonably provided by parties other than information system vendors.

Due to the heterogeneous nature of the existing information systems, the architecture must abstract the existing information systems and expose their data content in a unified form. Therefore the architecture must define a mechanism for describing the data content that is exchanged. The technology with which the connectivity is implemented must be independent of software platforms and operating systems.

Standardization efforts should be used as guidelines for defining the data content that is used inside the integration architecture. Great input to the vertical integration can be extracted from ISA SP95, but for integration of O&M activities on the factory floor level, the standardization work is still ongoing. Results can be anticipated from the OpenO&M consortium, for example.

3 SERVICES AND SERVICE FRAMEWORK

Service Oriented Architectural style (SOA) is a software paradigm developed around the Web Services technology. In service oriented architectures, data and functionality are decoupled from each other, and dependencies between the service requesters and providers are minimized. The requesters and providers are said to be “loosely coupled”. (Booth, D. *et al.*, 2004)

The service oriented approach suits well the business environment of industrial operation and maintenance. Services that do not themselves hold any significant amounts of data, but transform it, can be implemented by the external service providers. The functionality of these services represents the special maintenance knowledge held by the service providers. This knowledge can be applied at various process plants, and it should not therefore be tightly coupled with data, which is always plant specific.

3.1 Value added services for O&M

O&M value added services are pieces of software that utilize the existing information system infrastructure in a production plant to create value addition to their users. The value addition is obtained of the existing O&M information systems by integrating them with these services, instead of using them solely for their original purpose.

In practice, the value addition can be anything from data access facilitation to complex process analysis and automatic control actions. A common denominator of the aforementioned is that the services help to make the O&M operations more integrated and effective. The value added services provide functionality, which is at its best when deployed outside the existing information systems.

They are sensitive to the state of the production process and available production and maintenance resources. Therefore process, production and maintenance information systems are the key sources of information for the value added services.

The value added services generate new information that flows back to the production plant and partner organizations and information systems. They can also generate notifications and perform automatic control actions. The services can be configured by the human users of both parties of the partnership model to produce value addition. The configurability of the services is a very important issue from the partnership perspective, because it makes possible for the services to encapsulate knowledge that might not be available for the other partner.

The information exchange requires consensus on the data models to be used. OPC XML DA provides a great basis for conveying single data items such as process measurements. On more complex data, such as maintenance work orders or condition monitoring data, other standardization efforts have a crucial role.

The operation and maintenance value added services can be categorized to three levels according to their complexity and the value added. Services on the lowest complexity level simply combine the information to one customizable view. The value addition provided by these services is the ease of access to the relevant information. The second level of service complexity is that the services refine the collected data and in this way create new information. The second level services can be used to produce key figures, such as OEE (Overall Equipment Efficiency), from the process of interest. Services at this level must possess and apply knowledge about how the information is calculated. They must also be able to maintain state and preserve process information. The third and the highest level services interact autonomously with their environment. Services at this level can act as high abstraction level controllers that control the work processes of production and maintenance.

A prototype of an intelligent value added service, called Reasoning Service, has been implemented by us. The service refines process measurement data into new, more abstract information, and into automatically performed actions that control the workflows of O&M. The transformation of data was performed using a fuzzy inference system, which can be used for both function approximation and classification tasks. The exemplary service is presented in detail in (Jaakkola, 2004). The prototype demonstrates the potential of standard interfaces such as OPC XML-DA as the enablers of systems integration. It also shows how modern AI techniques can be utilized within O&M value added services.

3.2 Service framework

A web service based framework provides supporting infrastructure for value added services (Kondelin, Karhela, and Laakso 2005). Figure 2 depicts layers of the developed service framework architecture.

The framework is independent of organizations and software platforms and therefore promotes the interoperation of information systems, exceeding the organizational boundaries. The common interface description and data model specification allow the value added services to connect to the data contents of other services.

Core services transform data from underlying legacy systems to the common data model of the framework. This way they bring the data content from existing information systems infrastructure to the reach of the value added services. The core services of the service framework are to some extent analogous with the vendor specific adapters of MIMOSA (MIMOSA, 2004). The core services, however, do not usually interact with each other directly, but through value added services. Also the

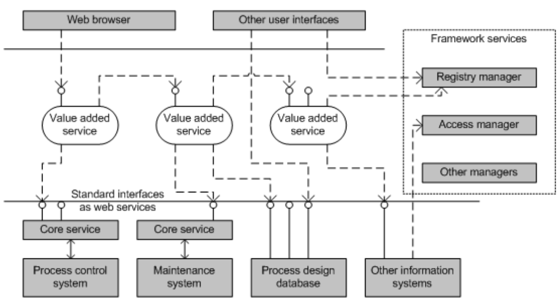

Figure 2: Service framework

data model of the service framework is not as explicit as the one of MIMOSA, but rather a generic meta-model.

The OPC XML-DA interface (OPC Foundation, 2003) has been chosen to be the data access interface of the service framework. Therefore, an OPC XML-DA wrapper, which relays Web service messages to an OPC DA interface, can be considered as a core service of the simplest kind.

Access control and the discovery of services are examples of issues that cannot be resolved in the web service environment only between the client and the service. The framework must thus include services that provide functionality for these issues. In the service framework, these kinds of services are called Framework Services. Framework services are common to all, and they do not represent any system or organization. Access Manager is a framework service that controls the authorization of users to the data content of the core services and value added services. Access control is especially important when the integration of information systems exceeds organizational boundaries. The discovery activity that is essential to the web service architecture is in the responsibility of the Registry Manager. The Registry manager provides similar functionality as UDDI, but typically its services are used at runtime instead of design time.

4 CONCLUSIONS AND FUTURE WORK

Based on requirements derived from current state of the art, a solution conforming to the ideas of SOA was proposed. The concept of value added services for O&M and the supporting service framework were thus introduced.

It can be concluded that the web service based architecture enhance the information management issues discussed. Firstly, internal information flows can be automated thus leading to enhanced internal collaboration of integrated operations. Secondly, the solution supports the organizational changes that have lead to networked O&M. Finally, better visibility from top floor into the O&M information is obtained, alleviating potential bottleneck problems of the value chains that characterize the current demand-driven business model.

Web services provide independent means to create interoperability between heterogeneous systems of industrial plants. However, in order to provide more advanced and dynamic reasoning and services, information must be semantically enriched. While information can certainly be better managed by utilizing the proposed solution, the tacit knowledge, present at plants and within partners still remains largely unexploited. Currently, we have begun is to research technologies that are semantically more advanced and to use these technologies in the challenging domain of O&M.

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