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PLANT CONNECTIVITY: INTEGRATION OF MACHINE TOOL CONTROL WITH MANUFACTURING OPERATIONS MANAGEMENT

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Abstract: *The paper presents a solution for event based bi-directional communication between a machine tool control and the manufacturing operations management layer according to ISA-95. The solution comprises a configurable middleware providing data transfer between SAP Manufacturing Integration & Intelligence using SAP Plant Connectivity and the SINUMERIK 840D numerical control using RPC SINUMERIK Computer Link.*
Key words: *NC, MES, RPC, Plant Connectivity*

1. INTRODUCTION

Machine tools on the shop floor can still be characterized as “islands of automation”, disconnected from the rest of the manufacturing enterprise. The integration of manufacturing execution systems (MES) with business level enterprise resource planning (ERP) systems promises to help manufacturers to benefit from increased flexibility, visibility and manufacturing control by bridging the traditional gap between the factory and the higher-level business systems. In order to accomplish this objective, manufacturers have to go beyond what traditional ERP and MES offer. Apparently, one of the most challenging issues in deploying a well-integrated enterprise information system is how shop floor equipment would be able to be linked to office-planning systems systematically and cost-effectively in guarantee of pertinent information being consolidated into the context of needs in different business unit domains (Ye & Qiu, 2003).

As stand-alone ERP systems have failed to cope with specific requirements of production ERP providers are forced to include MES solution capability and integration to equipment automation. SAP addressed this requirement by introducing SAP ME (Manufacturing) and SAP MII (Manufacturing Integration & Intelligence) to the market. Communication is supported by SAP Plant Connectivity (PCo), an extensible connectivity infrastructure that allows creation of instances, which provide data service functions between SAP applications and industry standard data sources, such as Object Linking and Embedding (OLE) for Process Control (OPC). PCo is built on the .NET framework using Web service technology and provides query execution and notification capabilities, which allow monitoring of data source items or tags for changes.

2. PROBLEM STATEMENT

Plant Connectivity (PCo) incorporates an agent instance that communicates with plant systems and subscribes to available plant system events. A subscription item is some object (simple or complex) in the plant system to be monitored. It may be a simple value, such as temperature, pressure, time, etc. or a complex item, such as an OPC A&E Notification. The agent generates notification messages based on incoming plant system events and user-defined business context. A destination system delivers notification messages to respective systems (SAP ME or SAP MII). Beside OPC DA and OPC A&E agents, in the latest release of PCo also an OPC UA agent adding notification support for object event changes and query execution support is available. OPC UA (Unified Architecture) is the most recent OPC specification from the OPC Foundation and differs significantly from its predecessors. The OPC Foundation's main goals with this development was to provide a path forward from the original OPC communications model (COM/DCOM) to a current infrastructure model (SOA) and introduce a cross-platform architecture for process control, while enhancing security and providing an information model (Stopper & Katalinic, 2009).

Since OPC UA servers providing the whole range of functionality required for the communication with numerically controlled machine tools are not available yet, we decided to develop an interface allowing bi-directional communication between SAP PCo and a SINUMERIK 840D numerical control.

3. OBJECTIVES

In building a MES system one is confronted with the following main challenges:

- processing the multiple, heterogeneous, asynchronous event-based information flow within the environment
- coping with the highly dynamic behaviour of the production system and represent the complex production process
- reacting appropriately to a variety of different events occurring in the production process (Füricht et al., 2002).

On the other hand flow of information from the MES to the machine tool control is necessary in order to provide tool parameters or NC programs. Therefore we decided to develop a configurable middleware communicating with the SINUMERIK numerical control via RPC SINUMERIK Computer Link and the socket agent of PCo. As PCo 2.1 does not provide bi-directional communication for the time being, we built a new agent into the PCO framework applying the agent software development kit delivered as part of SAP PCo 2.1. This agent receives notifications, data and commands from the MII and transmits them to the middleware using socket communication.

4. SYSTEM DESCRIPTION

The architecture of the communication solution is shown in Fig. 1. On top level MII receives notifications (machine status, alarm messages etc.) from or transmits commands to the control layer (CNC). The machine tool control is a SINUMERIK 840D with RPC SINUMERIK Computer Link based on Remote Procedure Calls. Message flow passes two additional layers in between, the SAP PCo and the ConIF-Interface that transforms messages into RPC-calls and vice versa. The ConIF-Interface has been developed using the RPC SINUMERIK-OCX development package that is an add-on product for the RPC SINUMERIK computer link. The MCIS_RPC.OCX encapsulates the RPC interface from RPC SINUMERIK in COM calls (Component Object Model).

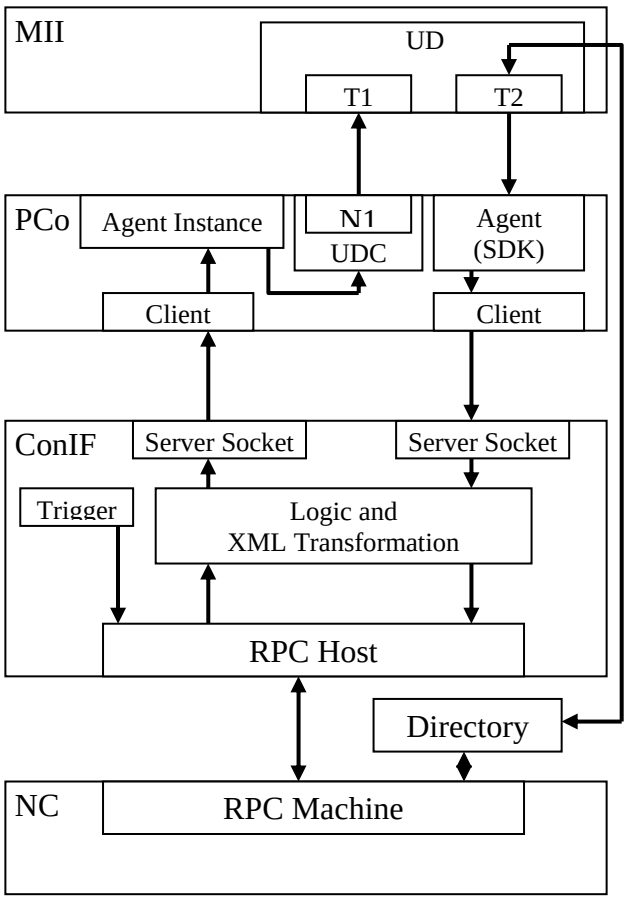

Fig. 1. Architecture of the communication solution

4.1 Message flow from CNC to MII

As soon as an alarm occurs or the machine status changes the ConIF-Interface receives an event. The respective data is packed into an XML Stream and transmitted to PCo via server socket. PCo hast to be configured for handling this stream. First of all a socket source channel hast to be created that establishes a connection to the outgoing server of the ConIF-Interface. Then an agent instance has to be established that handles the incoming data. For this agent a notification that subscribes to the socket source channel is defined. A trigger function decides under which circumstances (filters and constraints can be defined with an editor) a notification has to be sent to the destination system. At last the destination system has to be defined by assigning the Notification to a MII transaction.

The ConIF-Interface also provides a polling function for a predefined set of machine tool parameters. According to a given sampling rate that can be set in the configuration of the interface these parameters are read from the machine tool control and then transmitted to the PCo the same way as described above.

4.2 Message flow from MII to CNC

While upward communication via socket can be realized by standard configuration, PCo 2.1 does not support socket connection for downward communication. We solved this problem by developing a customized agent for PCo using the software development kit delivered with PCo 2.1. A how to for creating custom agents is described in Kansal 2010. This agent receives data or commands from MII through the tag query function and transmits them to the ConIF-Interface that transforms them into RPC calls for the machine tool. The XML stream that is to be transmitted to the ConIF–Interface is "hidden" in the tag name (max. 128 characters). Long XML streams must be split into a number of tags. The agent rebuilds the original stream, connects to the ConIF-Interface and transmits the stream to the incoming server. This mechanism is a temporary workaround as in the next release of PCo the downward communication shall be a standard functionality.

The following example shows a query of the machine status. The command is packed into an XML stream and transmitted to the incoming server of the ConIF-Interface:

```
<XMLCom>
    <Order>T_MACHINE_M</Order>
    <OrderNum>0</OrderNum>
</XMLCom>~
```

The ConIF-Interface then releases the respective RPC call. The machine tool control delivers the required information that is transformed into an XML stream by the ConIF-Interface and returned to PCo via socket:

```
<XMLCom>
    <RPC_typ>R_MESSAGE_H</RPC_typ>
    <Sender>AxSINCOM.AxMachine</Sender>
    <ClampCubeSide>0</ClampCubeSide>
    <DockPos1>0</DockPos1>
    <DockPosStatus1>0</DockPosStatus1>
    <MachineMode>0</MachineMode>
    <MachineStatus>0</MachineStatus>
    <NCProgramm>Testprogramm1</NCProgramm>
    <OrderNum>0</OrderNum>
    <WPC1></WPC1>
    <WPCStatus1>0</WPCStatus1>
</XMLCom>~
```

Also NC programs can be automatically transferred to the machine tool by MII. The respective program is copied to a file directory shared with the machine tool control. Then the filename of the program is transmitted to the ConIF-Interface via PCo. The interface releases a RPC call for the machine tool control with the filename as a parameter and the CNC reads the program from the shared directory.

5. CONCLUSION

The presented bi-directional communication solution for integrating a SINUMERIK machine tool control into an SAP System using SAP Plant Connectivity framework proved to be robust and easy to handle.

6. REFERENCES

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