Supporting Production Management for Manufacturing

Joberto S. B. Martins* and Fernando W. Cruz*

*DSC/GRC: Computer Networks Group
Federal University of Paraiba - UFPB, Campina Grande, Brazil
Email: job@brufpb2.bitnet Telephone: +(55) 83 3224 4032

Abstract—Production and operations management (POM) is an important activity in all organizations which can make use now of protocols and networking technologies for providing more efficient tools. In this paper, we describe the implementation of a set of primitives suitable for supporting production management (PM) applications. The PM service is based on the Manufacturing Message Specification (MMS) protocol of the Manufacturing Automation Protocol (MAP) architecture. The MMS is modeled according with its companion standard and the solution is oriented for manufacturing.

Keywords - Manufacturing Process, Production Management, Operation Management, Manufacturing Message Specification, MMS, Manufacturing Automation Protocol, MAP, Companion Standard, Flexible Manufacturing.

I. INTRODUCTION

Economical and social transformations which have occurred in the last few years have changed the behavior of the consuming market. Consumers new demands include aspects like high quality, customized features and low prices among others. As a result of this new market paradigm, new technologies were developed to give flexibility and efficiency in the production process

Production and operations management (POM) is one discipline that supports the tactical and strategical decision-making process in organizations through the use of models, simulations, tables and decision trees among others methods and techniques [1]. Influenced by this new paradigm, POM has to evolve and one possible alternative in this evolution is the use of computer networks services.

As far as computer networks are concerned, they can be seen as the basic bloc for supporting communications and integration in computer integrated manufacturing (CIM), flexible manufacturing systems (FMS) and related technologies [2] [3] [4]. There are various networking technologies for industrial applications in terms of standardized architectures oriented to the reference model for open systems (OSI/ISO Model) [5], de facto standards [6] and proprietary solutions [7]. Each one try to accomplish the functional requirements at the different levels of the industrial hierarchy (factory floor, cell, plant and general management).

One of the most important contributions to communications in manufacturing is the MMS - Manufacturing Message Specification protocol [8]. MMS provides a message service between supervisory computers and programmable equipment used in the factory-floor like programmable logical controllers, robots and CNCs among others. The MMS is recommended for use in the MAP - Manufacturing Automation Protocols architecture [9] and can pragmatically be used in any other protocol architecture.

MMS modeling allows the definition of Companion Standards (CS) to treat the particularities of each specific equipment in such a way that, as a final result, communication among them is possible [10]. Being so, there is a considerable effort nowadays in defining companion standards for diverse types of equipment like programmable controllers, robots and CNCs [11] [12] [13] [14]. Among other aspects, these CS define service classes, the mapping of the MMS generic services to the equipment and other HW/SW manufacturing dependent mapping.

PM applications are partially related with the monitoring and control of the shop-floor level equipment, they need communication services to perform this task and is certainly important that the solution proposed should be standardized.

In this paper we present a support for production management applications suitable for manufacturing which make use of the MMS services. The PM service support presented follows partially the Rae's proposition for a PM companion standard [10]. We introduce, as an alternative, a simpler implementation which binds the MMS interface instead of implementing a full client/server model normally used in the basic protocol.

II. MMS PROTOCOL AND SERVICES

MMS is a generic protocol defined to support the exchange of messages among equipment in the shop-floor level. In order to guarantee uniform communication among these equipment it describes the equipment as a VMD (Virtual Manufacturing Device) in a client/server model [15] [16] (Figure 1).

Fig. 1. MMS vision to access remote equipment

From the user point of view, the MMS services are obtained through primitives which cover almost all equipment (types and functionalities) commonly used in manufacturing [17]. MMS services are organized in functional units as indicated in Table I. In the adopted model a server process maps the generic services to the equipment and it is composed by an executive function,
one or more domains, zero or more station operators and a virtual file system (optional).

| MMS Service Functional Units | Description |
|-----------------------------|-------------|
| Context Management          | Basic service to initiate and conclude contexts among users, cancellation of notifications services and reception of protocol errors, beyond negotiation of options to establish connections. |
| VMD Support                 | Service to obtain VMD status, identification and renaming in a remote equipment. |
| Variable Access             | Service to access memory allowing reading and writing. Permits reception of information, obtains attributes and defines or suppress unnamed, disperse and named variables, list of named variables and list of typed variables. |
| Event Management            | Service to allow the definition, suppression, management and recovery of status and attributes of real time events (local or remote). It allows to define actions in relation to events. |
| Semaphore Management        | Service to allow the definition and recovery of the status of semaphores, synchronization, control, and coordination of common resources among MMS users. |
| PI Management               | Service to allow the creation, suppression, status change and recovery of Program Invocation attributes. |
| Operator Communication      | Service to allow communication between alpha-numerical terminals and operators through I/O operations. |
| Journal Management          | Allows to register main events of a remote system in a file. Allows read, write, initialization and recovery of logs. |
| Domain Management           | Service to allow the download and upload of programs in a equipment (local or remote). |
| File Management             | Optional service to manage remote files located in control equipment or servers. |

Table I

MMS SERVICE FUNCTIONAL UNITS

III. PRODUCTION MANAGEMENT

The organizational structure of the manufacturing process can be view as a collection of activities. These activities include areas like marketing, engineering, production, operation and others.

In particular, production and operations management are activities related with the effective creation of products and services. Strategic decisions have to be taken in these activities, for instance, with respect to the project of the product, type of process to be used, layout of the plant, human resources being used, inventory control and, also, management of equipment such as CNCs, AGVs, PLCs, robots and others.

Considering more simple situations with a low-level of automation, there is some sort of assisted management in which workers participate in the production process. In this case, messages are exchanged among workers through terminals who, in turn, control the equipment.

Semi-automatic plants, in general, have a smaller number of workers controlling the factory-floor and production management is aided by the direct monitoring of some equipment.

For highly complex plants, there is little or no human operation and, in this case, there are highly precise equipment like sensors, actuators and PLCs, working in a synchronized fashion and monitored by a central of operation through a computer network (Figure 1).

IV. BINDING MMS SERVICES TO PRODUCTION MANAGEMENT

The MMS protocol is generic and defined to support the exchange of messages among factory-floor equipment such as programmable controllers, robots, and AGVs, among others. In this scenario, Companion Standards (CSs) are specified in order to map the generality of the MMS to the specificity of the above mentioned equipment (Figure 2).

Fig. 2. MMS companion standards

Companion standards and the MMS itself, are implemented in a client-server model where the server corresponds to the actual implementation of the CS and is responsible for mapping the MMS services requests to the real equipment being used.

The support of production management applications by the MMS protocol may, however, be implemented in a more simplified model where:

- Users have a more friendly interface than that provided by the MMS; and
- There is no demand for an explicit set of asynchronous primitives/services or where the asynchronous services may be implemented in a polled fashion.

Asynchronous services are more frequently used in process control applications [14] for the generation of alarms, event notification and other real-time constraint dependent services. Production management applications, by its turn, are less dependent of asynchronous services as far as its functionality may be supported by a synchronous set of primitives invoked by the user. This suggests, in effect, that the client-server approach being used to model the MMS applications through CS definitions may be dropped for the PM solution. In this case, the PM application will simply use the defined MMS servers for the manufacturing system according with the client-server model, without being necessarily implemented in this way. That was the solution we’ve adopted.

For PM applications the solution used, instead of defining a new CS, was to define an interface, implemented as a library (PM_LIB), with support to different protocol architectures (Figure 3).

Being so, the first step was to define a MMS binding to a generic set of PM applications. This corresponds to the definition of an equally generic set of primitives where one possible solution is that proposed by Rae [10].

In this way, the different PM activities like inventory control, quality control, process monitoring and maintenance, among others, can make use of these new communication services in a integrating manufacturing environment.
It follows a summary of the Rae’s proposition for a production management (PM) companion standard (Figure 2). It was implemented in the PM_LIB module with a set of new services as proposed by Martins in [18] and [19].

V. SERVICE UNITS

PM systems demand for the execution of many different tasks. These tasks are described as set of functions organized as Service Units and, each unit, corresponds to a set of primitives with a defined mapping to the basic MMS service.

The basic service units defined, as proposed by Rae, are control, monitoring, quality, maintenance and error handling. It follows a short description of their functionality, primitives and MMS mappings.

A. Control

The control service unit deals with the preparation of the environment to start a production cycle. This preparation corresponds to machine set-up, material handling, tools preparation, software downloading and machine control. The Table II illustrate the primitives that are used to perform these tasks.

| PM_LIB PRIMITIVE                | FUNCTION                    |
|---------------------------------|-----------------------------|
| PM_Prep_Tm                      | Preparation of tools        |
| PM_Prepare_WP                   | Preparation of work-pieces  |
| PM_Set-up                       | Machine setup               |
| PM_Transfer                     | Transfer of item between processes |
| PM_Load-Unload                  | Material load/unload        |
| PM_Store                        | Item storage                |
| PM_Transmit                     | Software download           |
| PM_Machine                      | Machine control             |

B. Monitoring

This service unit corresponds to the monitoring of equipment, environment and personnel in a production cycle (Table IV).

C. Quality Control

Quality control information concerning raw materials and manufactured products are gathered for inspection control. This task is accomplished by the primitive PM_INSPECT.

| PM_LIB PRIMITIVE                | FUNCTION                    |
|---------------------------------|-----------------------------|
| PM_Status                       | Monitoring of hardware status |
| PM_Manpower                     | Personnel monitoring        |
| PM_Environment                  | Environment monitoring      |
| PM_Absence                      | Personnel monitoring        |

D. Maintenance

Two types of information exchange are required to perform preventive maintenance and corrective maintenance. The first one is a summary of maintenance requirements to prevent production failures which can be periodically sent (primitive PM_REPORT). The second corresponds to the actions required to perform corrective maintenance (primitive PM_SERVICE).

E. Error Handling

This service unit reports about failures which have occurred during the execution of the primitives defined by the PM support (both PM and MMS underlying them). In a few words, this service unit allows a human operator to be informed about an anomaly in the system. The primitive defined is PM_ERROR.

F. Mapping PM Primitives to MMS Services

The Table IV presents the relationship between the basic primitives defined for PM and the MMS functional units.

| PM_LIB PRIMITIVE                | FUNCTION                    |
|---------------------------------|-----------------------------|
| PM_Prep_Tm                      | Operator Communication      |
| PM_Prepare_WP                   | Operator Communication      |
| PM_Set-up                       | Operator Communication      |
| PM_Transfer                     | PI Management               |
| PM_Load-Unload                  | Operator Communication      |
| PM_Store                        | Operator Communication      |
| PM_Transmit                     | Domain Management           |
| PM_Machine                      | PI Management               |
| PM_Status                       | VMD Support                 |
| PM_Absence                      | Variable Access             |
| PM_Inspect                      | Operator Communication      |
| PM_Report                       | Operator Communication      |
| PM_Service                      | Operator Communication      |
| PM_Error                        | Error Type                  |

VI. PM_LIB NETWORKING SERVICES

One practical aspect of providing a set of adapted services (primitives) for PM is to consider:

- Support for multiple network architectures; and
- An user friendly interface.

Multiple network architectures were supported by the use of a network adapter as illustrated in the Figure 4. This module behaves like a network driver mapping the primitives generated by the MMS module to the type of transport interface available for the network architecture and operating system in use. Considering our implementation, the network adapter links the MMS module available to the transport layer provided in the Unix/TCP/IP/Ethernet environment for Suns [20]. This module is generic and configurable in order
to pragmatically support multiple PM_LIB networking frequently available in industrial plants.

The objective of this solution is simply to provide flexibility and shouldn’t be taken as the final way of implementing a network for manufacturing as far as, for doing this, standardized architectures should be considered.

The PM_LIB module is a library of functions (implemented in C language) which maps the PM primitives and services described in the section V to the basic set of MMS primitives and services.

Networking services were provided in two ways. Firstly, a set of library functions is available for direct linkage with the PM application providing a way of implementing complex production management systems in complex manufacturing systems. Secondly, a set of predefined screens is available in order to support those less complex production management systems which need more human interaction than automatization. This is typically the need of medium and small complexity systems. The screens conception assumes an user-driven operation for the human to computer interface and is as friendly as possible in order to couple with the basic requirement we’ve imposed to the package.

VII. CONCLUSION

Production management is a multi-disciplinary activity that has received many contributions from various disciplines. Nowadays, computer networks are a reality and, as such, can provide communication services for the factory-floor which can support the realization of the production management functions.

The support of production management services in networks implemented either as a companion standard or, for instance, as a binding using library functions is currently under study for standardization. In this sense, one of the objectives of this work was to find out one possible way of implementing these services taking into consideration basic premisses like simplicity and flexibility for use in the integrated manufacturing environment.

Although very simple, the final package created demonstrated to us the viability of running PM applications over different industrial networks. The current phase of the development corresponds to the qualitative analysis of the service primitives in order to extend the Rae’s proposition to cover a probably wider range of PM applications.

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Fernando W. Cruz - Master student in Computer Science in the Computer Networks Group of the Federal University of Paraíba - UFPB. Fernando has interest in computer networks topics like manufacturing management, protocols for manufacturing management and MMS - Manufacturing Message Protocol.

Prof. Dr. Joberto S. B. Martins - Professor at Federal University of Paraíba (UFPB) and PhD in Computer Science from Université Pierre et Marie Curie - UPMC, Paris (1986). Leader of the GRC research group on Computer Networks, Manufacturing Management and Telecommunications. Previously worked as Invited Professor at Universidad de Paris VI and Institut National des Télécommunications (INT) in France and as key speaker, teacher and invited lecturer in various international congresses and companies in Brazil and Europe.