An Object Oriented Tool for the Definition of the Structure of the Process User Layer for Industrial Fieldbuses

A.P. Kalogeras, K. Efstathiou, S. Koubias and G. Papadopoulos
Applied Electronics Laboratory
Division of Electronics and Computers
Department of Electrical and Computer Engineering
University of Patras
University Campus, Rion
GREECE

Abstract: The quest for greater flexibility in the industrial environment, leads to the installation of industrial Local-Area Networks (iLANs). Such networks may be either Fieldbuses or networks for the solution of problems at the Shop Floor level. The need for interoperability and the creation of a vendor independent environment have led to the creation of a special committee under the auspices of the Instrument Society of America (ISA), for the definition of a single standard for fieldbuses, that will in the long term replace the various already available commercial de facto standards. This paper handles with problems associated with the Upper Layers of the OSI-RM as defined for Fieldbuses and presents a case study implementation.

Keywords: Fieldbuses, MMS, Network Management, User Layer, Interoperability

A.P. Kalogeras received the B.Sc. in Electrical Engineering from the Department of Electrical and Computer Engineering at the University of Patras, Greece. He is currently a Ph.D Candidate and Research Engineer at the Laboratory of Applied Electronics in the Department of Electrical and Computer Engineering, the University of Patras, Greece. His research interests comprise industrial networks, CIM and communication software for industrial applications.

K. Efstathiou received the B.Sc. in Electrical Engineering from the Department of Electrical and Computer Engineering at the University of Patras, Greece. He is currently a Ph.D Candidate and Research Engineer at the Laboratory of Applied Electronics in the Department of Electrical and Computer Engineering, the University of Patras, Greece. His research interests cover industrial networks, communication software for industrial applications and PLL design and implementation.

S. Koubias received the B.Sc. in Electrical Engineering from the Department of Electrical and Computer Engineering at the University of Patras, Greece. He received the Ph.D in Electrical Engineering from the Department of Electrical and Computer Engineering, the University of Patras, Greece. He is currently an Assistant Professor at the Laboratory of Applied Electronics in the Department of Electrical Engineering, the University of Patras, Greece. His research interests cover multimedia applications, telemedicine, Local-Area Networks, industrial networks and CIM.

G. Papadopoulos received the B.Sc. in Electrical Engineering from the City College, New York. He received the M.Sc. and Ph.D in Electrical Engineering from MIT, USA. He is currently Professor and Director of the Applied Electronics Laboratory in the Department of Electrical and Computer Engineering at the University of Patras. His research interests include electronics, microprocessor based design, industrial networks, communication electronics, telemedicine, signal processing, computer vision and home information systems.

1. Introduction

Communication is possibly the most essential element for the achievement of a high degree of integration into the industrial environment. This integration is in turn mandatory for the achievement of a high degree of flexibility, which is one of the keywords for the survival of any kind of industry in the highly antagonistic world market of today. The communications needed in the industrial environment may be described using a four-level hierarchy comprising the Field Level, the Shop Floor Level, the Plant Level and the Corporate Level [1].

The problem that arises nevertheless derives from the diversity of the manufacturing devices that need to be interconnected. A short list of the devices that may be interconnected at the Field or Shop Floor Levels will include sensors and transmitters, various types of actuators, regulatory loop controllers, programmable logic controllers, safety shutdown systems, multipoint data acquisition systems, historical archiving devices, human interface workstations, chart recorders, indicators and displays, gateways to higher-level communication networks, bridges and temporarily connected devices.

The need for universal services for communication with all the devices mentioned above, is more than clear. This presupposes the existence of real open systems, that is compliance to the OSI-RM. The provision of a common communication platform is also necessary, such a platform being the Manufacturing Message Specification (MMS) protocol.

The aspects of device interoperability and interchangeability add further to the flexibility in the industrial environment. The provision of such features would result in the creation of a vendor-independent and thus extremely dynamic and open industry.

2. Industrial Networks

Both the Field Level and the Shop Floor Level are designated to solve problems associated with the interconnection of those devices in an industrial environment which are directly involved with physical data. Due to this fact, it is not always easy to draw a clear dividing line between the networks that are used to interconnect field devices and Shop Floor programmable devices. Fieldbuses and Shop Floor networks are in this context, complementary tools for the promotion of integration in the industrial environment.

The main Fieldbuses, that have become de facto standards and which are commercial products widely used. are the Factory Instrumentation Protocol (FIP) [2] promoted by the WorldFIP, and the PROFIBUS [3] developed by SIEMENS. Much more fieldbuses exist but they are comparably less influential than the two mentioned above.

The most influential Shop Floor network is the Manufacturing Automation Protocol (MAP), first used by General Motors. An European proposal for a Shop Floor network is provided by the Communication Network for Manufacturing Applications project (CNMA) [4], which utilises various network protocols such as fieldbuses, MAP and TOP.

The absence of a standard for fieldbuses has led to the creation of the ISA/IEC SP 50 Committee which is working towards developing a fieldbus standard. At the same time CENELEC has defined WorldFIP, PROFIBUS and P-net as intermediate standards for Europe until the ISA effort is successfully completed.

All of the Fieldbuses mentioned above use a three-layer architecture that is based on the OSI-RM. More specifically they comprise the Physical, the Data Link and the Application Layers with a vertical Network Management Layer. The Shop Floor networks implement all seven layers of the OSI-RM. Regardless of the implementation followed in the lower layers, all Fieldbuses and Shop Floor networks use the Manufacturing Message Specification protocol (MMS) at the Application Layer (Layer 7). This protocol was introduced by MAP and is an essential element for all industrial networks.

3. The MMS Protocol

One of the thorniest issues relevant to the integration into the industrial environment is the development of a common communication platform that could handle the diversity of the interconnected devices. Such a platform should provide universal services, applicable for communicating with diverse field and programmable devices supplied by different vendors. Manufacturing Message Specification (MMS) presents such a platform [5].

The MMS is the ISO/IEC 9506 Application Layer standard. This standard defines

a) the operations that can be performed on the models that have been defined, and the messages needed to be exchanged between systems to action the operations,

b) a protocol controlling the transfer of messages between diverse systems, and

c) a notation for the abstract syntax of the protocol control information and messages that are exchanged between systems.

The basic concept of MMS is the so-called Virtual Manufacturing Device (VMD). A Virtual Manufacturing Device represents the standardised view of structure and behaviour of real time manufacturing services, that is it defines the externally visible behaviour of an

MMS server application process.

For example a VMD is defined within the MMS server application process. It constitutes the portion of an information processing task which makes available for monitoring and/or control, a set of resources and functionality associated with a real manufacturing device. In other words a VMD could be regarded as a specification of the externally perceived behaviour of an interconnected manufacturing device.

All MMS services make use of a Client Server architecture. The MMS Server for a particular service instance is defined as the peer communication entity, that behaves as a VMD for this particular service request instance. The MMS Client is the peer communication entity which uses the VMD via a service request instance. Thus the VMD model is directly associated with an MMS Server describing its actions and as a consequence the commands an MMS Client may use.

In order to describe the MMS service model and the associated service procedures, the MMS standard uses a technique of abstract object modelling. According to this technique abstract objects, their characteristics and the related operations are described. The objects that are defined are abstract and contribute to better understanding the MMS service procedures and their effects. However, at the time when the services of the MMS are implemented, the abstract objects and the concepts described in the MMS model are mapped to the real device. Thus a real device is viewed externally as conforming to the MMS standard by having those characteristics described in the object modelling technique.

MMS defines the external as well as the internal behaviour of manufacturing devices. The external behaviour is well-described in the VDU of a manufacturing device. The description of the internal behaviour is necessary for supporting the definition of the externally perceived aspects as well as its placement in the OSI environment. A wide range of operations are supported by the MMS protocol:

- uploading and downloading
- task management
- variable and data access
- semaphore management
- event management
- journal management
- file management.

4. The User Layer

As mentioned in the previous section, the use of the MMS protocol defines a common platform for the communication needs of diverse devices interconnected via an industrial network. This protocol is nevertheless indifferent to the meaning of the data that are read/written from/to the network devices.

MAP proposes the definition of specific standards for each kind of a device, called Companion Standards, that would attach to the data transmitted their exact meaning and would define the usage of the MMS so that real world functions are implemented.

The ISA-SP50 approach involves the definition of an eighth layer in the OSI-RM, called the User Layer. The SP50 Committee appointed a Subcommittee to define the user needs [6].

The demand to define the actual user needs, requires a model for the user layer. The definition of such a model combined with the use of extensive services from the Application Layer, is sufficient for the complete definition of the user needs. The approach followed by the ISA-SP50 Committee for the definition of such a model was based on several existing Distributed Control Systems (DCSs) and Programmable Logic Controllers (PLCs) that were widely used in the industrial environment.

One of the underlying elements of the Fieldbus User Layer architecture is the Function Block. Each Function Block may perform data acquisition, control or output. A Function Block contains an algorithm which handles its control function, a database where the algorithm stores or retrieves data from and one or several parameters or attributes which may be accessed and changed via the network.

The definition of a model for the User Layer would result in the provision of devices with predefined algorithms, that is algorithms that comply to the standard, which would for this reason present the same steady and dynamic performance while executing. This evolution will render the industry vendor independent, as all the devices complying to the standard will be interchangeable.

According to their degree of compliance to the standard, the different industrial devices could be classified as interconnectable, interworkable, interoperable or interchangeable. The two former categories of devices refer to the minimum properties which are necessary for the performance of an interconnection via an industrial network. The two latter ones are relevant to the ability of providing devices with more advanced features like the interoperability of code or the interchangeability of the devices themselves.

According to the architecture of the User Layer each device may be viewed as a Physical Node, consisting of one or more applications that execute locally, which are called Logical Nodes. Each Logical Node would perform data acquisition and/or output, and would use for this, special Function Blocks. The demand for control could be solved by using special control Function Blocks. Finally, there are the attributes or parameters and the database which may be altered during the execution of the Logical Node.

5. Implementation of An Industrial Fieldbus

Our application is based on the development of an industrial fieldbus. This fieldbus uses the RS485 standard as its Physical Layer and the SDLC protocol to solve problems at the Data Link Layer.

The Application Layer is based on the MMS protocol and a subset of its services is being developed. These services include variable management, environment management, program invocation management and domain management services.

An important element of the built network is the Network Management. The network management having been implemented contains three kinds of services: those relevant to Performance Management, those related to Fault Management and the Configuration Management services [7].

The Performance Management module is responsible for the run time collection of data from the physical nodes of the network. It also assesses the physical node and the network performance.

The Fault Management module comprises detection and diagnosis of system failures. A mechanism has been implemented for the correction of some of these errors (e.g. automatic network reconfiguration), while a similar mechanism exists for pointing to the user's errors that cannot be automatically corrected as, for instance, problems related with the physical medium.

Finally the Configuration Management caters for the initial configuration of the physical nodes, i.e. the initial downloading of the code that is necessary and the starting of the execution of the Logical Nodes that reside on the Physical Nodes.

6. A Tool for the Configuration Management

The goal of the Configuration Management as stated before is the preparation of the Physical Nodes according to the user needs. This may be translated into the following actions:

- Downloading of the Logical Node codes that need to be executed on the Physical Nodes of the network
- Starting of the Execution of the Logical Nodes remotely.

Both actions have as a prerequisite the determination of the code of the Logical Nodes by the User. This may be done following many different approaches. For instance the user could merely write down the code in a high-level language.

Our idea involves the use of a graphical language for the creation of the code needed for a specific industrial application.

A special tool has been implemented which permits the user to actually design his application using objects that correspond to specific Function Blocks and which implement the above mentioned graphical language. The tool uses a user-friendly interface which requires only the selection of the Function Blocks and their interconnection so that the needs of the application are met. Then the appropriate code is automatically generated.

This tool refers to an off-line procedure, that of the application code generation. Nevertheless the configuration management module heavily depends on the results of this off-line tool in order to be able to initialise the Physical Nodes of the network. The configuration tool becomes active when the network is for the first time initialised and whenever a new Physical Node functionally enters the network.

Then it retrieves all required data from the graphical tool and uses the adequate MMS services to set the configuration of the application that the network must execute.

7. Conclusions

The application described above presents an industrial fieldbus designed to solve problems in the industrial environment. The implementation of the specific network is based on a four-layer architecture consisting of the Physical, the Data Link, the Application and the User Layers of the OSI-RM, supported by a vertical Network Management.

This proposed structure lets the user benefit from the installation of a fieldbus and provides an integrated way of handling the creation of its application. The application gains in flexibility while the implementation of a sophisticated network management makes it dynamic.

The encapsulation of the principles of the User Layer emerging standard into the design of the specific tool for the application implementation, adds such powerful features as interoperability and interchangeability to the system`s features.

The implemented system has been successfully installed in six collaborating industries.

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