THE FINS PROTOCOL FOR COMPLEX INDUSTRIAL APPLICATTIONS
A Case Study

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Abstract: This paper presents a comparative approach on the use of different industrial networks configurations and industrial communication protocols. Some aspects, that may influence the right choice of the most indicated protocol for each industrial network configuration, are discussed. It is presented a case study and two configurations networks implementing two industrial communication protocols. The respective advantages and disadvantages are presented. All the detailed aspects including the data exchange are presented too. The obtained results are extrapolated for other similar industrial applications.

1 INTRODUCTION

This works appears on the context of developing and implementing new solutions for industrial networks implementation. This line of research is being developed by a team from the School of Engineering of University of Minho and involves some departments of the School.

The first results, here presented, are the first one obtained from an initial study that it is intended to be more complex and exhaustive.

Industrial communications have significantly evolved since their appearance in the 1970s. Faster and more reliable communication protocols have been proposed and deployed in industrial applications (IEC 61784-2).

The necessity that the companies have to improve their competitiveness has lead to many developments on this field, related with more complex industrial networks applications and with more complex communication protocols elaboration. This increasing of competitiveness is a constant objective for all the companies in general and for the Portuguese companies, in particular.

In order to facilitate the management and control of manufacturing processes it is, currently, very important the flexibility of the implemented management and control systems for the manufacturing processes. For that accomplishment, it is necessary a fast access at the information, means that allow a fast decisions according the manufacturing process behavior and, more important, the possibility of improvement of the manufacturing systems efficiency.

With the development of the communication of the industrial networks, with the evolution of the industrial communication protocols and the increasing of the exigency level - characteristic of the manufacturing process control - the knowledge and the know-how associated at these realities is becoming crucial on the development and improvement of competitiveness of the industrial companies.

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In this paper it is intended to compare and conclude about industrial network configurations and to compare industrial communication protocols too. Some propositions for the best communication protocol to be applied on some industrial network configurations are also presented.

In order to achieve the main goals proposed on this paper, the paper is organized as follows: Section 1 used to present the challenge of the work. In section 2 it is presented a background about industrial networks and industrial communication protocols. Further, section 3, it is presented a case study that permits the application of two industrial network configurations and, also, two industrial communication protocols application. Section 4 is devoted to the presentation of the developed work followed by the Section 5, where are presented and discussed the obtained results. Finally, section 6, there are presented the main conclusions of this study and some guidelines for the future work.

2 BACKGROUND

In this section it is presented a brief overview of industrial networks and some of the most used communication industrial protocols.

2.1 Industrial Networks

The industrial networks can be implemented considering several types of controllers.

Among these controllers, the Programmable Logic Controllers (PLCs) are the most used due to their robustness when submitted to industrial environments which are characterized by adverse conditions (like magnetic fields, vibrations, dust, noise, among others).

With the current increase of industrial networks, the availability of user friendly environments and software tools that allow a better use of the industrial networks capabilities is also improved.

The access to different network nodes must be fast and must allow supervising all the processes even if they are physically independent.

An industrial network may have different components; therefore, it implies that the connection type between these components may be different, leading to the need of using sub-networks. Thus, to define some order and criteria on these links, it can be considered a set of hierarchical levels related to a common industrial network. These hierarchical levels can be defined by different ways and using different criteria. Nevertheless, the pyramid CIM (Computer Integrated Manufacturing) (ISA-dS95.01-1999) is a good approach for illustrating these levels (Figure 1).

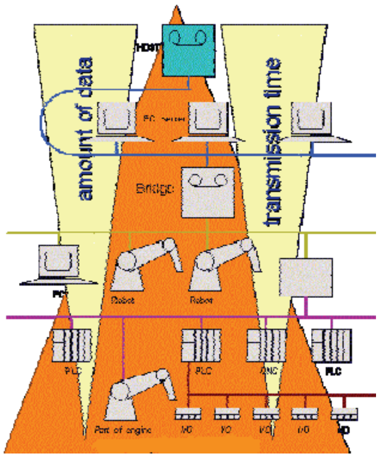

Figure 1: CIM Pyramid (ISA-dS95.01-1999).

The CIM Pyramid is divided in levels concerning the type of application to be controlled. The considered levels are Management, Control, Process, and, finally, the Inputs and Outputs variables.

The Management level is concentrated on all the information concerning to the network. Usually, it is used a Personal Computer (PC) in which it can be seen all the performance of the plant using a Supervisory Control and Data Acquisition (SCADA) system (Pires and Oliveira, 2006).

At the Control level it is established the connection between PCs and PLCs.

The Process level is characterized by the controllers and PLCs for the industrial process control.

Finally, the Inputs and Outputs level includes the sensors and actuators devices. This is the lowest level of the CIM Pyramid. It is also the closer level to the plant, where the network is applied.

In the Management level, as in the Control level, the type of network used is a Local Area Network (LAN) (IEEE 802.1AB-2005) as for example the Ethernet (Felser, 2005).

At the Process level other types of networks are used. One of the most implemented is the PROFIBUS network (PROFIBUS International, Liu *et al.*, 2007). Also, at this level, the Actuator/Sensor Interface (AS-I) network may be used (Lee, 2001).

The Ethernet appears with the main goals of reducing costs, increasing dependability, sharing the information and the physical resources in the same transmission environment by using a coaxial cable.

The Ethernet technology has, as physical devices, the coaxial cables with small and large diameter, or the plaited pair of cables.

With the Ethernet network some topologies are possible: star, tree or ring type configurations. For the communication between the several devices there exist some transmission environments: the Simplex, where the transmission is done in a unilateral direction; the half duplex, where the transmission is done from and to each device; and the full duplex, where each device simultaneously transmits and receives information.

The Profibus network has different functionalities for its communication protocols: the profibus Fieldbus Message Specification (FMS), the Distributed Peripherals (DP) and the Process Automation (PA), where the physical transmission is done by RS485. The profibus FMS is a protocol used on the PCs and PLCs communication, but Ethernet network is substantially increasing on this domain application. The DP profibus is used for the communication between small PLCs and for the communication between PLCs and the controllers. With the transmission environment RS485, it can be used a complexity until 32 devices, including the first initial node of the connection. Usually, this node is a small PLC. The PA profibus network is implemented to link sensors and actuators, connected to a master PLC that centralizes all the relevant data to the control system.

The AS-I network is used for the lowest level of automation systems. There are about 80 international developer companies that use this type of network.

This is a low cost network and easy to expand. Like Profibus, it is allowed the use of a maximum of 32 devices. The maximum allowed length is about 100 meters.

2.2 Industrial Communication Protocols

With the increasing of the competitiveness and the set of different PLC products existing in the market, it is usual, in an industrial plant, to coexist different types of PLCs. The communication between these systems is necessary in order to accomplish all the benefits proposed by the industrial networks.

For the communication between these physical devices, different solutions in the set of industrial communication protocols are used. The advantages of universal protocols (open protocols) seem natural, because they allow the exchanging of data and information between different types of systems.

In this group of protocols, one of the most used is the serial communication protocol. But there are others, like the Synchronous Serial Interface (SSI) and the Bi-directional Synchronous Serial Interface (BiSS). As open protocol, the Profibus (previously described) is also very used.

There are, also, other protocols that are restrict and proprietary of the controllers' manufacturers. For instance, the Hostlink and the Factory Interface Network Service (FINS) protocols are two examples of a large set of these closed protocols (Kizza, 2005).

The main advantage of using closed protocols is improving the simplicity of network implementation and configuration. The manufacturers of these protocols have well adapted software tools and a very structured set of configurations that considerably help the designers.

The main advantage of open protocols is that they can be used and shared by different devices from different manufacturers. Using these protocols it is possible to exchange data and information between several commercial devices. The characteristics of these protocols are similar, no matter the device manufacturer, so different companies use them as a way to promote their own products and also to increase the competiveness between the device manufacturers.

In fact, if it is necessary to expand the industrial network, adding new devices, these protocols have real advantages when compared to the closed protocols. In addition, they are at low cost. The main reason to decrease the cost of these protocols is that the devices manufacturers intend to increase the competitiveness (Kizza, 2005).

3 CASE STUDY

The automated line production which was used in this study is a didactic Modular Production System (MPS) of the Mechanical Engineering Department Automation Laboratory of University of Minho, in Portugal. Although being didactic, this equipment is a well achieved simulation of a real system. Its command module is being used in real line production systems. All the control tasks are assured by a Programmable Logic Controllers (PLCs) Network specially designed for the purpose (figure 2).

This system is composed by five modules, named as follows:

Module 1 – Distribution
Module 2 – Test

Module 3 – Processing
Module 4 – Transport
Module 5 – Separation

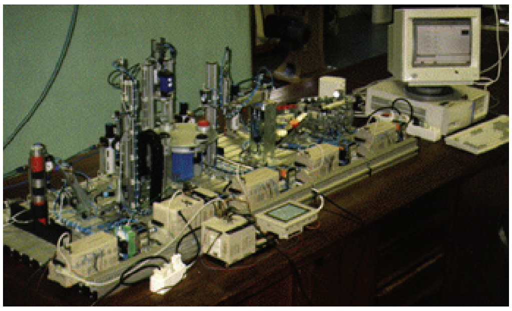

Figure 2: Modular Production System.

These modules have an independent control, each one being controlled by a single PLC, all the PLCs being controlled by a PC.

The identification of the component type is made in the module 2. The control programming assure that on the module 5, the components are assorted by size, colour or material, as well as rejected components, each one being directed to an appropriated conveyor.

In order to obtain some results comparing the communication protocols it was decided to configure the control structure in two different kinds of networks really implemented in industrial systems.

In a first step, the PLCs corresponding to each module were connected in a network, in a parallel configuration, as shown in figure 3. All the networked PLCs are at same level of control (network N1).

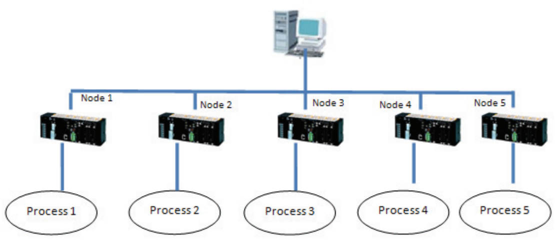

Figure 3: Scheme of the implemented network (step 1 of the study).

In a second step, the MPS was separated into five independent modules, where each one represents a sub-network, as illustrated in figure 4, network N2.

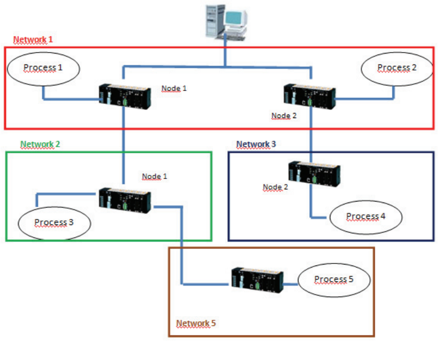

Figure 4: Scheme of the implemented network (step 2 of the study, with sub-networks).

The used protocols for this study were the Hostlink and FINS protocols from OMRON Company (www.omron.com).

On the first step approach it was used the Hostlink protocol and on the second step approach it was used the FINS protocol.

4 DEVELOPED WORK

Networks N1 and N2 were implemented (www.omron.com).

In the case of network N1, Hostlink protocol is often employed. Each PLC has a dedicate identification number (ID). The configuration frame includes: the PLC ID number, the definition of the action to be performed, e.g. to read a process variable value (counting pieces in a process line production) or to send a command value to the working system (switching on an actuator).

The command frame includes the following fields (Figure 5): constant parameters definition, the first one indicates the frame starting point and the terminator parameter designates the ending point; the node number is the PLC ID number for communication; the header code and the text are the definition of the action and the data to be exchanged in the communication process, respectively.

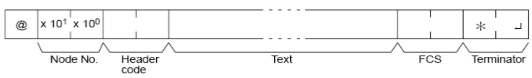

Figure 5: Hostlink command frame.

The response frame to the previous command is shown in Figure 6. The start and ending points are identical to the command frame. The difference is in the end code parameter definition which corresponds to an indicator of success or error in the transmission line established.

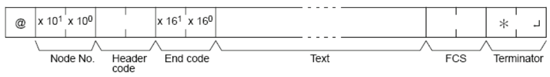

Figure 6: Hostlink response frame.

This protocol is adequate for using in a small network with parallel PLCs configuration which can be a constraint when working with complex control systems. To overcome this limitation and when sub-industrial networks are implemented (Network N2), FINS protocol is an adequate solution.

Figure 7 shows the structure of the command frame sent to the network to communicate to the PLC. The frame is similar to the Hostlink protocol but it includes the specific FINS command, the action to be performed, the target sub-network and the corresponding PLC, in order to establish the communication. This frame is detailed in figure 8.

In the frame it must be defined the destination PLC and to where (which network and PLC) the response message should be returned.

Figure 7: FINS protocol frame.

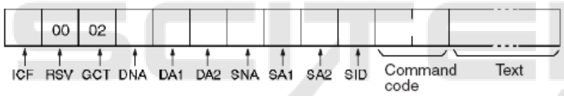

Figure 8: Parameter specification in FINS command.

Between the FINS characteristic parameters, the parameters DNA, DA, SNA and SA1 are particular important, as they define the PLC communication command target and the destination of the response message. DNA is the destination network address, DA1 is the destination node address and in order to define to where the response message should be sent, the SNA, source network address ans SA1, source node address, must be configured.

5 RESULTS DISCUSSION

Hostlink and FINS protocols were tested and compared in two types of industrial networks: a simple network N1, represented in Figure 3 and a more complex one, N2, shown in Figure 4.

First, network N1 was tested. Two values were read from the PLC memory position Core Input Output (CIO) starting from position number 10. Table 1 shows the configuration of the command frame for writing, sent by the personal computer (PC) to the PLC, by using both protocols, Hostlink and FINS.

Table 1: Command frame for writing.

Protocol	Frame
Hostlink	@00WR000A0001000237*
FINS	@00FAF000000000102B0000A0000020001 000200*

Table 2 shows the response frame sent by the PLC to the PC, also employing both protocols.

Table 2: PLC response frame to writing command.

Protocol	Frame
Hostlink	@00WR0045*
FINS	@00FA00400000000102000040*

The test was repeated but for reading command of two values in PLC memory CIO which are in position 9. Tables 3 and 4 show the command for reading sent by the PLC and the corresponding response frame sent by the PLC.

Table 3: Command frame for reading.

Protocol	Frame
Hostlink	@00RR000900034A*
FINS	@00FAF000000000101B000090000 0278*

Table 4: Answer table from PLC.

Protocol	Frame
Hostlink	@00RR0000000001000243*
FINS	@00FA0040000000001010000000010 00240*

Analyzing Tables 3 and 4 it is verified that the frame lengths are different. This is due to the fact that the configuration parameters are diverse. In this case, network N1, Hostlink protocol is easier to configure, the frames are shorter, being more adequate for the application system.

A second configuration was tested, network N2, where the MPS process is controlled by the PLC connected to a specific sub-network.

As Hostlink protocol cannot be used in industrial systems where sub-networks are configured, only the FINS protocol was implemented.

Table 5 presents the command for writing sent from the PC to the PLC positioned in a sub-network and the corresponding PLC response command. The command consists of writing two values starting in position 10 of CIO memory.

Table 5: FINS writing command/response frames.

FINS protocol	Frame
Command code	@00FAF8000020101000000000001 02B0000A000002000100020A*
Response command	@00FA00C0000200000001020000 010100000025002232*

Table 6 tests the command for reading two positions in PLC (placed in the sub-network) CIO memory starting from position number 10.

Table 6: FINS reading command/response frames.

FINS protocol	Frame
Command code	@00FAF800002010100000000000 101B0000A0000020A*
Response command	@00FA00C0000200000001010000 010100000025002231*

As it can be seen in Tables 3 to 6, the frames lengths are different in all tested cases, being the FINS frame larger than the Hostlink. FINS protocol needs more parameters to configure the communication. For a correct and successful data transmission, all the FINS parameters must be defined even if they have null value.

In the Hostlink code, the writing and reading command frames make use of two specific characters, namely, RR and WR, respectively.

In FINS protocol the code is implemented using two hexadecimal values, four characters. For example, the code 0101 is for reading and 0102 is for writing. Both can be used to read and write in any PLC memory position. On the contrary, Hostlink protocol needs other commands to write in a different memory position. Both frames signal when the communication is successful.

Apart from having different frame lengths, Hostlink and FINS have also different data transmission capacity. FINS has a maximum capacity of 1115 characters while Hostlink has a lower capacity, 131 characters.

In summary, with FINS protocol we can access the whole network, including the PLCs that are in a sub-network. By using such a network it is possible to monitor and manage the whole line production from a working place.

For a correct use of both protocols, it is necessary to know the network type. If two PLCs are connected by a profibus link, the PLC slave cannot be accessed if both master and slave PLCs are in the same network as the PC. In profibus network, the slave device periodically sends to the master the memory positions, configure by the network manager.

6 CONCLUSIONS AND FUTURE WORK

This paper presents part of the on-going work regarding industrial networks design for complex systems.

An automated line production, a didactic Modular Production System (MPS), was used as the case-study. In spite of being didactic, this equipment is a well achieved simulation of a real world controlled system. All the control tasks are assured by a Programmable Logic Controllers Network specially designed for the purpose.

The communications protocols Hostlink and FINS used as information coordination methods between the PLCs and the production equipment control system were described and tested.

Although being a proprietary communication protocol, FINS becomes particular important due to its simplicity, economy of time and development costs.

In the near future, we are going to implement, test and discuss other types of industrial protocols using the demonstration system. An extensively comparative study for evaluating the protocols' performance will be carried on.

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