Internet-based Real-time Remote Monitoring and Control: Convergence of Data and Control Network using LonWorks

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Abstract. This paper presents work in terms of interfacing control networking system with the data network for remote monitoring and control of industrial systems. LON (Local Operating Network) technology is used as the fieldbus platform and Ethernet protocol based LAN network has been used as data networking system for realisation and verification purposes. Without loss of generality, a high-speed spindle system was chosen as the industrial machine system due to its availability within the laboratory.

1 Introduction

Recently, flexible distributed remote monitoring and control of industrial systems is gaining momentum for greater transparency and productivity [1]. The demand towards agile manufacturing strategy has been recognised [2]. Forward-looking industrial environment require more sophistication and flexibility in response to need for unified and coherent operation of control and management functions within one networking platform. As a result there is a need to interface data network with the control network to meet this up-coming requirements. Control-networking systems are available which is generically defined as fieldbus technology [3]. Commonly available data networking systems are LAN, WAN, MAN and so on.

This paper presents work in terms of interfacing control network with the data network for remote monitoring and control of industrial systems. LonWorks technology from Echelon Inc., USA is used as the fieldbus platform and Ethernet protocol based LAN is used as data networking system for realisation and verification. The paper is arranged as follows. In the first section a review on aspects of control and control networking systems is presented. Next, the need for interfacing data network with the control network has been justified. Third part of the paper describes the software and interfacing circuits developed for achieving remote monitoring and control of an example systems. Final part integrates the systems for realisation and verification. Results are provided based on observation.

2 Control systems scenario

Because of rigid nature, centralised control scheme is getting obsolete [4]. The counterpart of centralised scheme is DCS (Distributed Control Systems). DCS has potential advantages over the former in terms of scalability, extendibility, dynamic-configurability (modifications during operation), and most importantly, the fear of central failure. Since the IO devices (sensors, actuators and switches) are distributed throughout the plant (machine, production system, assembly system etc.), DCS is seen to be the effective scheme whilst considering communication, modularity and flexibility. The tremendous advances in the field of digital communication, semiconductor technology, industrial protocol and software technology have triggered the researchers to discover the requirements for the design of flexible distributed systems for real-time monitoring and control. The distributed system employs local decision-making capabilities at the point of interaction (IO). Although the distributed control are found in the literature the traditional centralised control systems are still in operation and it is a matter of fact that the DCS dimension has not fully dominated the former one due mainly to following reasons.

- No common international agreed standards are available in order to advocate open systems.
- Lack of knowledge on selection and integration of off-the-shelf tools and platforms to meet the requirement.
- Reluctant to replace the well-captured and familiar older version.

2.1 Fieldbus; The control networking systems

Fieldbus is a generic term used within industrial automation and control field [5]. Fieldbus is a digital serial communication system, which includes a protocol, hardware and supporting software for multiplexing control signals over a single communication channel. Since it multiplex any kind of signals, it is suitable to implement DCS strategy. In other words, fieldbus can be used for the realisation of distributed control and it is considered as the first step of implementing distributed control architecture because of their low cost and ease of installation.

Irrespective of target platform (plant) structure, the basic-building blocks of any fieldbus-based distributed control networking system includes a protocol for communication, nodes to accommodate distributed control task, transceiver for channelling the control data onto the network, compiler and installation software for the generation of control code and downloading, communication medium (OF, wire, power line, RF etc.) for data transformation and a development workbench (host computer). The protocol is a set of rules, which governs the formatting of real data and scheduling the transactions of formatted data in the control network. A node executes the control task and finds its position in between the transceiver I/O field devices such as sensors, actuators and switches. The heart of each node is the processor since a distributed system is one in which there are several autonomous but interacting nodes that perform sensing, monitoring, control and other functions within a defined application. Each node in the network implements the protocol for sending and receiving the messages. User-written control programs are developed with the compiler that resides within the workbench and then loaded to the nodes. Fig.1 illustrates a typical fieldbus based distributed control scheme. Some of the available fieldbuses are LonWorks Technology, CANbus, FIP, WorldFIP, ISA, IEC, ISP, HART, P-NET, BACNet, DeviceNet, Bitbus, EHS, Profibus, SP50 [4] etc.. For further information about fieldbus technology and systems refer [5-7].

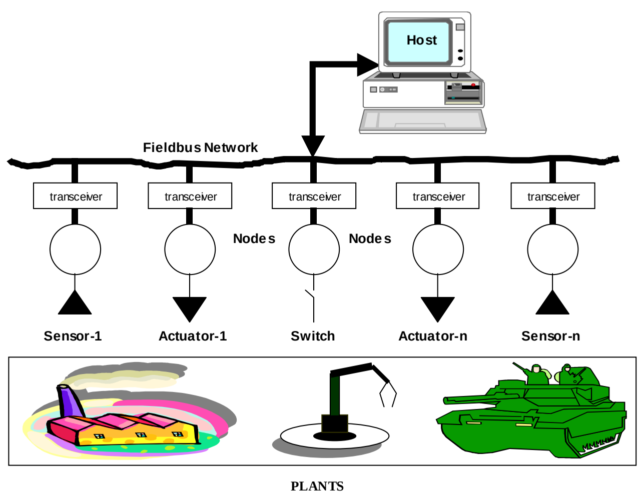

Fig. 1. A Typical Fieldbus-based DCS Solution

3 The need for interfacing DN with CN

Enterprise-wide networking system has been established with data networking system. Fieldbus technology based distributed control scheme has also been implemented in many industries [3]. The concept of *total automation* is emerging. Total automation in taken to mean as interfacing of data network with the control network. For novice practitioners and researchers the following questions will arise.

- Whether it is necessary to interface these two types of networking system?
- Why two kind kinds of networking systems exist instead of one?
- If interfacing is a requirement and consequently accepted, then the question may arise whether it is possible to realise the thought using only one kind of networking system?

The answer to the first question is that the interfacing is barely necessary in order to achieve more flexible way of monitoring and controlling the system remotely. Since IT-based data networking systems are available, the dedicated networking-system for implementations of such concept (remote monitoring and control) is considered to be costly. Not only in industrial applications, but the concept can be applied to home automation and control applications. Some of the applications are listed below.

If the price of the fuel increased overnight, the program holding the price configuration at the remotely located fuel stations can be modified instantly through data network. Since there are many fuel stations (even for a particular company) distributed geographically, the control network (automating the fuel station) located at the fuel station can be interfaced to avail the tremendous facility provided by the data networking system. This kind of implementation is already there in real applications but the work presented here is an interfacing of data network with the fieldbus type system; since the fieldbus technology is considered to be the accepted standard for future.

If the engineer is working in the office room at the moment, engaging the machine at work in the factory floor then the situation may demand to supervise and control the machine from his or her office room. The situation is more intensive if the engineer is forced to work a couple of hours more within the office.

If anybody whether or not has forgotten to lock the main door of his or her house and suddenly it appears in the mind, the node (controlling the lock of the main door) that is connected to the control network (which is again connected to the data network through a home PC) at home can be addressed and ordered to lock the door instantly through data network.

If the CEO wants to know whether or not all the machines and systems are working as per schedule he or she may monitor the operation remotely and can give direction to the technicians working in other floor for needful action.

The above facts are seemed to be well known but in real industrial avenue the concept is still at the rudimentary stage. The existence of two kinds of networking systems is due to the reasons that the underlying requirement of bulk data communication and control data communication are very different. There has been some confusion between fieldbus technology and the DN as they adopt the similar concept of digital signal communication. DNs usually are computer networks providing for communication between them in a geographically larger area. The access to the DN is achieved with a microprocessor based controller and a Medium Access Unit (MAU). For a DN configuration, large quantities of data (in the order of megabits per second) are transmitted from one node to another. The timing of messages and their transfer is not critical again. A control network on the other hand, interconnects field devices (sensors, actuators and switches) in rugged industrial environments. Message based data, however, in small quantities, is transmitted in a time that is pre-determined. Fieldbus conforming to the OSI model typically omit some of the OSI layer functionality, in order to meet the real-time requirement. Therefore, two kinds of networking systems are required for implementation and for this an interfacing has to be designed. This answers to both the questions cited above.

4 Interfacing design

LNS network kernel was used for the design of monitoring and control software to for the purpose of interfacing and monitoring and control. Thus the software consists of three modules, namely, 1) module for interfacing, 2) for monitoring and supervision, 3) control module. IBM compatible Pentium II PC with Windows98 operating system has been used as the host workbench. Visual C++ is used as the developing language because of its object oriented features and characteristics. A brief description on the tools used in this work is presented below. Fig.2 illustrates the structure of the implementation.

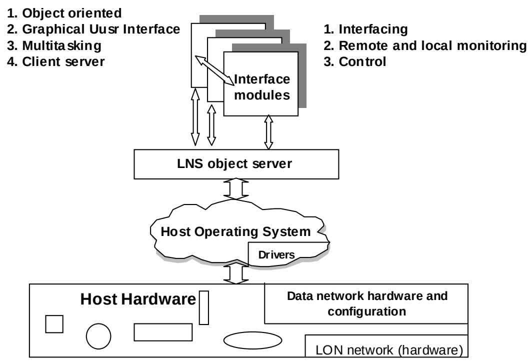

Fig. 2. Structure of the interfacing

4.1 IBM PC:

IBM PC is very popular and in many application areas such as academic, industrial, business and entertainment. Since the architecture has various ports, slots, and services it is very much suitable not only to use as the host workbench but it can be used for remote monitoring control applications [8].

4.1 Windows98

Most of the applications environments are now requiring multitasking operating systems for software development and later used of the executable software. Windows98 is a multitasking operating system having GUI features [9].

4.3 C++

Most of the software recently developed is based on Object Oriented (OO) philosophy. OO based technology inherits convincing features in terms of data abstraction, encapsulation, inheritance and polymorphism. These features are very much essential in order to facilitate transparency, reuse, extendibility, portability, size of the program and complexity [10].

4.4 LNS

LON (Local Operating Network) is called LonWorks technology has been developed by Echelon Corporation U.S.A. LonWorks is a fieldbus. The most important development tools for building LON fieldbus based control networks are NodeBuilder (described in the next section) and LNS (LonWorks Network Service) kernel. Although LON system is a proprietary fieldbus system but due to its architecture and conformant to ISO/OSI seven layer model its applicability is getting momentum in many industrial applications including home automation [11-12].

LNS is the control networking industry's first multi-client network kernel. Much like a standard operating system, which implements the fundamental operating task of the computer, the LNS network services encapsulates common operations, providing the essential directory, installation, management, monitoring, and control services required by control network applications. In addition LNS provides a standard interface, enabling multiple network applications (interface, monitoring, control etc.) from multiple vendors to operate. The LNS architecture combines the power of client-server architecture with object oriented, component-based software design. LNS for Windows incorporate Internet Protocol (IP) for remote application, and it is designed to work with the most common development platforms including rapid application development tools (RAD) thus offering the fastest way to being control on-line with all other information systems. The LNS ActiveX control grants access to the LNS Object Server, which provides its network services to an LNS application through a collection of LNS objects. To accomplish any given operating, the LNS application defines an object using the Object Server and invokes that object's appropriate method and properties. LNS Object Server objects are organised into a class hierarchy. A class defines a set of properties, methods and events, and each object is an instance of a class. Each object can be either a single object or a collection of object [13]. LNS Object Server hierarchy can be seen from [14]. The objects are used for the development of the interfacing, monitoring and control modules.

5 Case study

Problem statement:

1. It is required to control and monitor the condition of a machine and
2. To control the door lock remotely by the use of a data network environment.

Following additional tools and systems were required to realise the aim of the objective. They are a representative industrial machine (target plant), NodeBuilder development tools, i.LON hardware and other interfacing circuits. Without loss of generality, a high-speed spindle system and a door lock were chosen as the target control platform because of their availability within the laboratory. However, the concept can be used for SCADA (Supervisory control and data acquisition) and other remote monitoring and control systems. NodeBuilder development tool, compatible to LON system, is a development tool for generating control code for the spindle system.

Three nodes are used for spindle monitoring and control and one node was used for door control respectively.

The heart of each LON based node is the Neuron chip (developed by Motorola and Toshiba), which contains three CPUs. One is for Media Access Control (MAC) and other two are for network management and application purposes respectively. The programming language used for writing control code is Neuron C which is based on ANSI C (American National Standard Institute) and is very simple and flexible due to existence of *network variables* (NV) and *when* statement. The NV concept greatly simplifies the programming of complex distributed applications. The Neuron C has been specifically designed taking into account of real-time programming features. There are 34 I/O functions, which can be used by the users for writing the application code for the nodes in the network. Other interfacing hardware used for this experiment are A/D converters, displacement sensors, IGBTs, current sensors and vibration sensor.

The high-speed spindle system controls the depth of cut during machining for high quality structured surfaces. The spindle is composed of spindle bearing system using an electromagnetic exciter. The displacement of spindle deformed by radial attractive forces generated by electromagnetic exciter. This electromechanical structure consists of four current transformers for measuring each winding coil current of four electromagnets, two capacitive displacement sensors for measuring the spindle displacements in x-axis and y-axis, a converter supplying electric power to the electromagnets according to control signal. Since the aim of this research work was not to design the control system of the above spindle system, emphasis has not been given on the design of control code, however, a brief description on fieldbus based design and development process has been presented in [15]. Fig.3 illustrates implementation scenario.

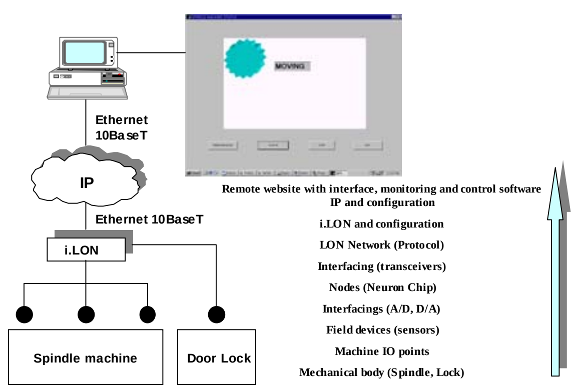

Fig. 3. Implementation Scenario

The spindle was monitored remotely. The remote computer was equipped with TCP/IP and LAN connection, and LNS based interface, monitoring and control software (developed in this work). The remote place was approximately 500 meters (although not significant, but it can be any place connection to the Internet terminal). The following were controlled and observed

- The machine was made run by clicking the Start/Stop button of the monitoring module.
- The status of the machine was examined
- The door was made locked (it was open deliberately) by using the buttons at the remote place.

6 Conclusions

Remote monitoring and control of industrial systems is an emerging area of research. There is a requirement to interface two types of networks (data and control) if it is required to monitor and control the system remotely. Control network implements the DCS based strategy within the factory floor according to control requirement. Data network is another kind of network used for accessing information from the remote places. The two networks can be integrated and interfaced to access the control data from the control network residing at the factory floor through the data network. This paper designs and establishes an integrating environment to realise the above concept. LON platform and systems were used for realisation, verification and validation of the objective. Emphasis has been given to use the fieldbus technology as the control network and Ethernet as the data network due to the reasons that both type of networking systems are considered to be full proof technology. The interfacing and observation was achieved by the use of NodeBuilder, i.LON, LNS, IBM PC, Visual C++, Windows 98 tools and systems. The interfacing software was developed using OO-based methodology and Client Server principle. Without loss of generality, a high-speed spindle system and a door lock were chosen as the control application platform.

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Monitoring and Controlling. Project controls are where the project manager makes their money. It is relatively easy to assign someone work. But how do you ensure the quality of that work? That the deadlines are met? Or that the cost is reasonable?Â It is used to control two of the most important aspects of the project: Schedule (time). Cost. The end result is a number, called a schedule variance and cost variance, which gives you an indication of how far behind (or ahead) of schedule and budget the project is.Â The project must be broken down into tasks and each task requires the following pieces of data: Start and end dates. A task budget. Thankfully most projects already have these defined. If you donâ€™t, you must unfortunately define them before you can measure against them. Based on the study [6], methodological foundations and proposals for the rational use and effective management of complexes of automatic motion control systems were developed based on the formation of a system for evaluating the performance of intelligent technical complexes. In modern conditions, it is necessary to ensure the effective implementation of motion control systems and to obtain a single concept aimed at improving the functioning of technical means of automatic fixation based on an assessment of their effectiveness.Â The program of monitoring and management of energy networks of intelligent buildings and structures.Â â€¢ The annual number of accidents in the considered area of the street road network after the installation of automatic technical systems. Uses real-time data to discover devices and build charts, network maps, and inventory reports. Is one of the most user-friendly network monitoring tools available. User monitoring can help bridge the gap between technical issues, user behavior, and business metrics.Â PRTG Network Monitor from Paessler is a free network monitoring suite that uses SNMP, packet sniffing, and WMI to monitor your network. Scan network segments to discover and add devices to monitor. You can choose between a range of sensors to monitor various segments of your network.Â Overall, Icinga is a scalable solution that gives you control over how you manage your environment. Icinga is available for Debian, Red Hat, SUSE, Ubuntu, Fedora, OpenSUSE, Raspbian, and Windows. An Introduction to control networks based on LONWORKSÂ® Technology. Content: 1 Introduction 2 Basics of LONWORKS 3 Neuron Chip 4 Neuron Chip I/O Models 5 Transceivers.Â Using the i.LONs, networked control systems can be monitored and controlled via Internet connections based on TCP/IP, RTC or DSL lines. Control Networks Rev 5.11 En. Â© 2004 by EBV Elektronik GmbH & CoKG An Avnet company| www.ebv.com. 4. An Introduction to control networks based on LONWORKSÂ® Technology.Â Test equipment for verification of data transmission (power line communication analyzer, protocol analyzer for LonWorks networks). Politique de licences de produits Echelon. To connect the Nortec Integrated Controller to LonWorks, BACnet IP or BACnet MS/TP (includes all Master functionality) the optional LonWorks or BACnet gateway boards (ProtoCessor gateway) must be used. This manual describes how to install and configure the optional LonWorks or BACnet gateway boards to connect the Nortec Integrated Controller to a building management system. This addendum manual is intended for use by engineers and properly trained technical personnel. Please read this manual thoroughly before installing and configuring the BACnet or LonWorks based network. If you have question...