Realization of Virtual Device Network(VDN) for Predictive Maintenance

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Abstract : Requirements for Distributed Monitoring and Control Networks(DMCN) differ greatly from those of typical data networks. Specifically, any DMCN technology which employs a filedbus protocol is different from IP network protocol TCP/IP. In general, one needs to integrate fieldbus protocol and TCP/IP to realize DMCN over IP network or internet, which can be viewed as Virtual Device Network(VDN). Interoperability between devices and equipments is essential to enhance the quality and the performance of predictive maintenance(PM). This paper suggests a basic framework for VDN using DMCN over IP network and a method to guarantee interoperability between devices and equipments.

Key Words : LonWorks, Device Network, Data Network, LonTalk, TCP/IP, Virtual Device Network

1. Introduction

Recent trends require that access to the device/equipment information be provided from several locations or anywhere in the enterprise. One example is virtual machine/manufacturing system(VMS) which utilizes VDN. Internet access is increasingly available and affordable, and along with the "internet" is the backbone of modern enterprise data networks[1]. Typical functions of such a system includes monitoring and control for diagnosis and remedy action in realizing preventive maintenance. VMS inevitably involves the implementation of Distributed Monitoring and Control Networks(DMCN). DMCN are generally equipped with smart sensors, controllers, and other CPUs which provide very useful information if utilized properly[2]. Fig. 1 depicts control network address range requirements in factory automation.Many sensors and actuators supporting various types of manufacturing processes are, however, seldom integrated into any real-time interoperable network. The concept of the inter-operable DMCN can be justified in this sense.

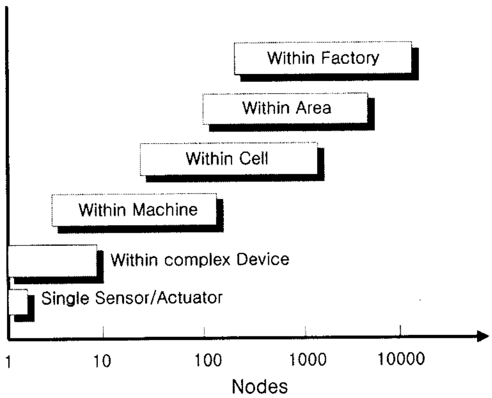

Fig. 1. Control network address range requirements in factory automation.

Requirements for monitoring and control networks are different in many aspects from those of data networks[3]. Gateways can be used to provide data access to control networks from other than fieldbus protocol. In addition, the data and supervisory control facilities that control networks support need to be accessed by a human operator or a personnel who may not be located near the control systems or plant floor. With the increasing use of local area data network such

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as Ethernet in the enterprise, it became a convenient means to access control network for data analysis and storage, and for monitoring and control functions.

The objective of this study is to suggest a basic framework for VDN using DMCN over IP network to better perform predictive and preventive maintenance in a VMS environment. A method to guarantee inter-operability between devices is also suggested.

2. Fieldbus Networks as Control Networks

Fieldbus is a generic term that describes a digital, bi-directional, multi-drop, serial bus, communication network that supports field devices such as sensors and actuators[4]. Using fieldbus as a means of industrial communication has several advantages :

- System reliability
- System flexibility
- System performance
- System size and inter-connectivity

The concept and design of DMCN is based on sensors and actuators integrated into any on-line (real-time) control network. The requirements for the infrastructure and capabilities of DMCN therefore need to be carefully evaluated. Among many available field-bus protocol mentioned above, LonWorks was chosen as the device control network for several reasons[5]. The most significant ones are its interoperability and intelligent/distributed nature :

(1) Interoperability : Users can design products according to interoperability guidelines. This means that every device will work with each other. The router connects the two channels in LonWorks which have different communication media or transmission rates. The sensor node converts measured variable to digital signal other than normal analog signal and sends it to network through a network transceiver.

(2) Intelligent/distributed network : The traditional master/slave type hierarchical systems in Fig. 2 can be made to work with smaller address spaces, but such systems are in fact an artifact of history. A better approach is a flat architecture that supports the address

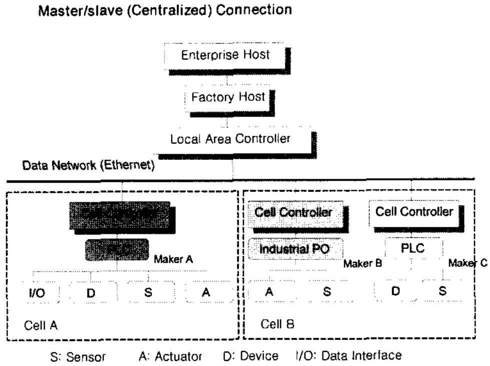

Fig. 2. Traditional master/slave type network

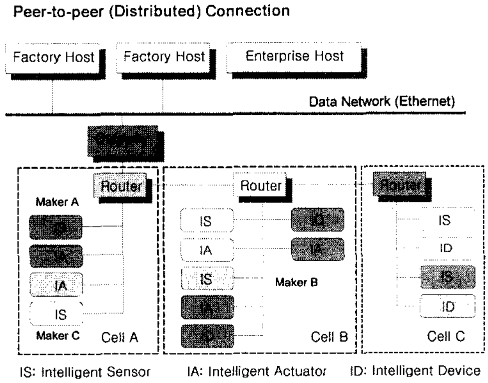

Fig. 3. Distributed (peer-to-peer) network

requirements of the entire system, but allows logical segmentation.

Fig. 3 shows the device network system composed of intelligent sensors and actuators. The distributed system is logically segemnted by function, to allow a modular implemntation. Within a flat archi- tecture, node counts indicated above suggest a flexible addressing scheme, one that can support small address spaces for small systems, and large spaces for buildings, factories and processing plants. Because each point in the network has intelligence, the system has no central pointer of failure. This is particularly true in distributed control networks where fault-tolerant is naturally resident.

3. VDN Using DMCN over IP Network

It is clear that IP (family of Internet Protocols including TCP/IP), is the integrating network for the enterprise. This makes it the obvious choice for

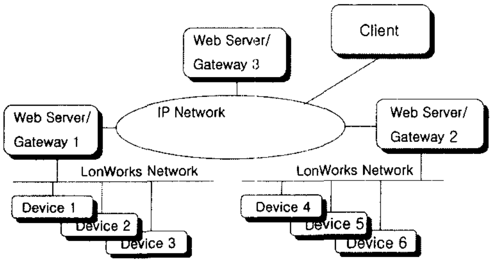

Fig. 4. VDN realized in distributed server-client environment using LonTalk over IP network

integrating(remote) device network with business networks via the internet. By integrating device network with IP network, multiple sites can be simply integrated into a seamless VDN. Fig. 4 shows the structure of VDN where independent servers for distributed monitoring and control functions communicate with each other over the internet. LonTalk over IP network utilizes a web serve with both Ethernet and LonWorks connection using a LonTalk over IP gateway. The Ethernet compatibility can support user to access IP network, and the LonTalk compatibility can support user to access LonWorks network form any workstation within a TCP/IP connection.

In this(web) server-client model, a server will control and monitor LonWorks network locally and clients can control and monitor LonWorks network remotely. The server obtains the LonTalk network variable from LonWorks network. The server then sends it to IP network using Ethernet connection. In the client sites, the client will read it out and send back the related control command through network variables.

4. Examples

4.1. Application to Equipment Effectiveness

Equipment utilization measures the fraction of total operating time in an observation period, hence the overall effectiveness of equipment[2]. Factors that affect the equipment utilization include time lost due to breakdown and setup adjustment losses. A key factor in calculating a reliable equipment utilization time is to perform a proper process parameter logging.

The monitoring node in this case is a digital input node. It typically has optically isolated input channels and the On/Off state of sensor is interfaced with this I/O device. If this device has no realtime clock in it, any change of state sensed by the sensor has to be propagated in the LonWorks network to the web server or further to the client over IP network for data logging. In order to minimize the network traffic, a "send-on-delta" technique can be used. In this technique, the sensed value must change by at least this amount before a new value is sent. The value of "send-on-delta" can be configured in the network by windows compatible plug-in function of LonWorks devices.

Current existing solutions implement the web-based control by using Java, CGI and External Helper program to control remote LonWorks devices over TCP/IP. In order to maintain the continuous connection between server and client, Java-based distributed server model can be considered. In addition, connecting LonWorks network with JAVA is a possible solution for easy-to-create visualization application[6,7]. Java applet allows the system to continuously monitor the processes and machines. With the help of visualizing JAVA applets, one can graphically monitor industrial control data in the comfortable and impressive web pages. Fig. 5 shows the typical web browser screen written in JAVA to monitor and control the LonWorks device for digital I/O. This web page was supplied by the web server/gateway developed in this study.

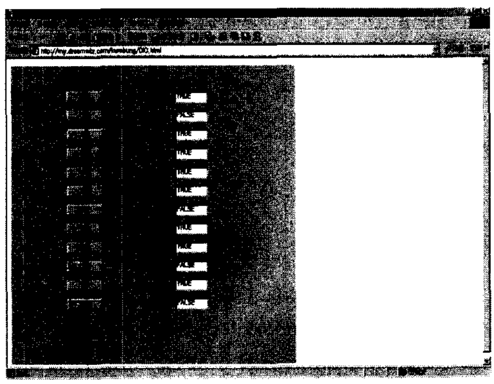

Fig. 5. Web browser screen to monitor digital I/O data. This page was written in Java

4.2. Evaluation of Equipment Reliability

PM interval can be adjusted by examining the historical trend of machine monitoring data or the process parameters. Such historical data updated in real time by the VDN will provide, for example, informations on how frequently alarm, alert and control limit conditions have occurred. These informations are then used to substantially reduce the PM frequency. The MMI(Man-Machine Interface) software package can be configured to assign alarm, alert, and control limits on the signal data to indicate an out of control condition on a particular device. In this case, "heartbeat" technology can be implemented. Heartbeat is a network variable update that is automatically sent if the network variable has not otherwise been updated for a certain length of time. This length of time is configurable in the network.

The open controller/monitoring function allows simple search for any alarm signal in the shared memory map in Fig. 6, which is in turn used for determining diagnosis and remedy solutions from the alarm list in database. In contrast to the above method, two types of methods are available for data retrieval from the LonWorks network, i.e., polling and binding. Although polling has benefit that no address tables entries of the nodes on a network needs to be modified, each node has to be polled individually, causing unnecessary network traffic. Bound connections uses the address tables of the nodes being monitored that needs to be updated if any change has been made. The advantage of using bound connection is that network variables are only updated when the data changes, reducing the unnecessary network traffics.

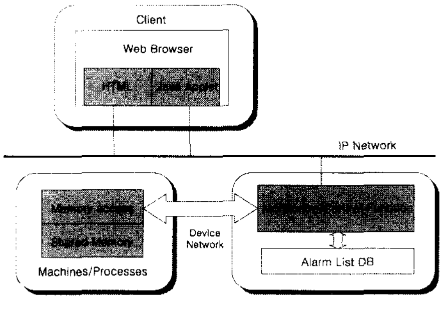

Fig. 6. Typical shared memory map method to retrieve data in the network

Each device in a LonWorks network is called a node. Different nodes can communicate with each other by means of network variables. A network variable can be propagated on the network and received by other nodes. Two types of network variables, i.e., input variables and output variables are used. These variables can be bound to each other, allowing output variables to be propagated to the input variables.

5. Conclusion

A basic concept that can be applied to VDN using distributed monitoring and control over IP network was suggested. Specifically, LonWorks technology was considered as control network. Connecting these remote LonWorks networks to the IP network can provide a powerful, integrated, distributed monitoring and control performance. A problem of security arising from the fact that a number of users access the VDN over the internet and a safety issue arising from the human-machine interface need to be resolved for practical implementation of VDN. Future work therefore includes implementation of a security and safety mechanism on distributed monitoring and control devices for real-time data collection and web-based tele-monitoring.

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