웹 기반 예방 보전에 관한 연구

최 기 흥
한성대학교 기계시스템 공학과
(2001. 10. 29. 접수 / 2001. 12. 10. 채택)

Web-based Predictive Maintenance(PM)

Gi-Heung Choi
Department of Mechanical Systems Engineering, Hansung University
(Received October 29, 2001 / December 10, 2001)

Abstract : Requirements for Device Networks differ greatly from those of typical data networks. Specifically, any device network technology which employs a fieldbus protocol is different from IP network protocol TCP/IP. In general, one needs to integrate fieldbus protocol and TCP/IP to realize device network over IP network or internet. 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 web-based predicted maintenance and a method to guarantee interoperability between devices and equipments.

초 록 : 디바이스 네트워크에 요구되는 사양은 일반적인 데이터 네트워크와는 판이하게 다르다. 특히 필드버스 프로토콜을 사용하는 디바이스 네트워크 기술은 인터넷 프로토콜을 사용하는 네크워크와 다르다. 일반적으로, 인터넷 상에서 디바이스 네크워크를 구현하기 위해서는 필드버스 프로토콜을 인터넷 프로토콜(TCP/IP)와 결합할 필요가 있다. 또한 예방보전의 적용예에 있어서는 각 디바이스간의 호환성이 매우 중요하다. 본 연구에서는 웹기반 예방보전을 구현하고, 디바이스간의 호환성을 보장하기 위한 방법을 제안한다.
Key Words : predictive maintenance, device network, data network, web, internet

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) where predictive maintenance is performed both on factory floor and in remote site through internet.[1] Internet access is increasingly available and affordable, and along with the "internet" is the backbone of modern enterprise data networks. Typical functions of such a system includes monitoring and control for diagnosis and remedy action in realizing preventive maintenance.

Such a 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] Many sensors and actuators supporting various types of manufacturing processes are, however, seldom integrated into any real-time interoperable network. The concept of the interoperable DMCN can be justified in this sense.

Requirements for monitoring and control networks are also different in many aspects from those of data networks.[3,4] Fig. 1 depicts the typical examples of device network and data networks. DMCN protocols such as fieldbus exist on the ground of these differences.

There are also some common requirements between device and data networks. Examples are security, reliability, and flexible wide-area and remote access. The business networking solutions are addressing these requirements in a complete and expanding manner. DMCN can take advantage of these capabilities by properly interconnecting the device network with data network

gihchoi@hansung.ac.kr

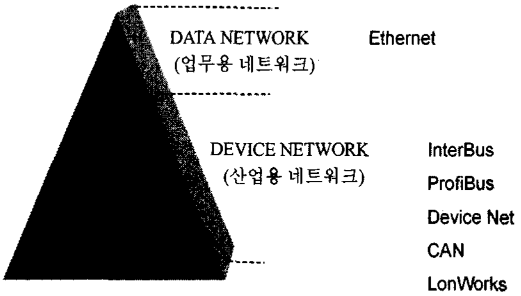

Fig. 1. Typical examples of control (device) networks and data network

components. Interoperability between devices and equipments is, however, essential to enhance the quality and the performance of predictive maintenance (PM). The objective of this study is to suggest a basic framework for web-based predictive and preventive maintenance in a VMS environment and a method to guarantee interoperability between devices.

2. Device(Fieldbus) Networks as Control Networks

Fieldbus is a generic term that describes a digital, bidirectional, multi-drop, serial bus, communication network that supports field devices such as sensors and actuators.[5] Using fieldbus as a means of industrial communication has several advantages:

- Reliability
- Low installation costs
- Fast start-up
- Easy implementation

Fieldbus systems for process control, automotive products and building automation are getting more and more attention. Intelligent, distributed network nodes communicate via various types of communication media and exchange data packets needed for either local or global decisions. Even if some data packets are lost, none of the cyclic transmitted messages may be lost in order to guarantee the correct behavior of the control systems. Most fieldbus systems propose mechanisms to detect modified or destroyed data packets caused by noise and interference on the transmission line. If a packet gets lost in an acknowledged service, the transmitting node is forced to retransmit this packet. There are numerous fieldbus systems available today. These include BACnet, CAN, CEBUS, IEEE-488, ISP, Interbus, Profibus, DeviceNet, LonWorks, WordFIP, etc.

3. Inter-operable (Open) Control Networks

There has been increasing interest by both end-users and device makers in interoperable (open) device control networks. Inter-operable device networks and devices could lead to the following benefits:

1) Reduction in development costs and time for highly automated manufacturing applications through a major change to the adoption of configurable, compatible block style network components. These components are selected on a price/performance basis rather than vendor dependency.

2) Network design and configuration tools which are widely applicable and not tied to vendor specific target hardware. These are also selected on a price/performance basis rather than vendor dependency.

3) Reduction in the cost of eliminating faults (fast identification and replacement of defective building block) and ease of service and maintenance of the building block network components. Service and maintenance personnel are trained to support standard network components.

4) Flexibility and adaptability of the network to changes in business direction.

5) Adaptations and alterations can be preformed by the end users on the basis of an interoperable modular network structure.

6) Ease of integration with current manufacturing information systems (MIS) or ERP systems.

4. LonWorks-based Distributed Control

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 fieldbus protocol mentioned above, LonWorks was chosen as the device control network for several reasons. The most significant ones are as follows[6] :

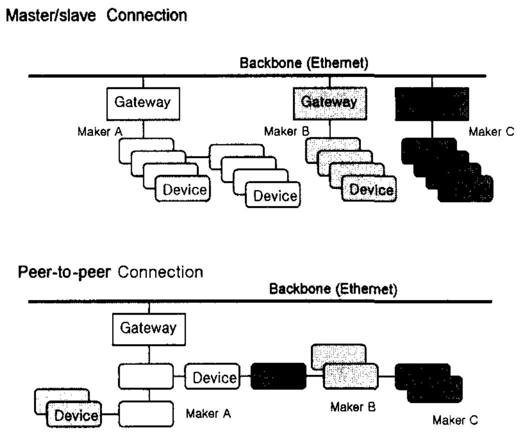

Fig. 2. Comparison of distributed network with the traditional master/slave type network

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. Depending on the communication media, data rates can rage from 300bps up to 1.25Mbps.

2) Intelligent/distributed network: 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. The distributed network based on LonWorks technology is compared with the traditional master/slave type network in Fig. 2.

3) Multiple media options : LonWorks supports multiple topologies such as Star, Bus, or Ring topology. Also supported are media such as twisted pair, fiber optic, RF and power line. Users can mix and match topologies or media in the same network.

LonWorks technology is the accepted standard in the semiconductor industry for implementing a DMCS as well as in the building automation industry.

5. Device Network 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 integrating (remote) device network with business net- works via the internet. By integrating device network with IP network, the Internet can be directly used for remote parts of a system with local enterprise subsystems via the enterprise LAN. In other words, by connecting device network via IP, multiple sites can be simply integrated into a seamless VMN. The VMN includes remote sites connected with monitoring/control applications located on the IP networks.

One important step to realize LonTalk protocol (for LonWorks) over IP is the protocol mapping between them. This can be accomplished by c programming between the LonTalk protocol-embedded Neuron processor and any host processor that support IP network.[6,7] Parallel I/O capability of Neuron CPU is essential in realizing protocol mapping and handshaking protocol needs to be implemented.[8,9]

Fig. 4 depicts handshaking protocol sequence. The handshaking protocol implemented by the Neuron chip firmware permits coexistence of multiple devices on a common bus. At any given time, only one device is given the option of writing to the bus. A virtual write token is passed alternatively between master (host processor) and the slave (Neuron processor) on the bus in an infinite, ping-pong fashion. The owner of the token has the option of writing data, or alternatively, passing the token without any data. In our example, a 16bit processor with separate Ethernet driver chip was used for host processor.

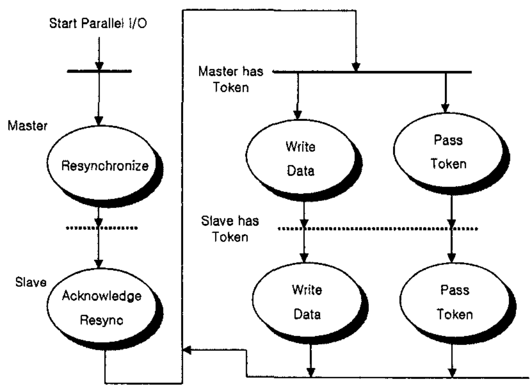

Fig. 4. Handshake protocol sequence between master and slave

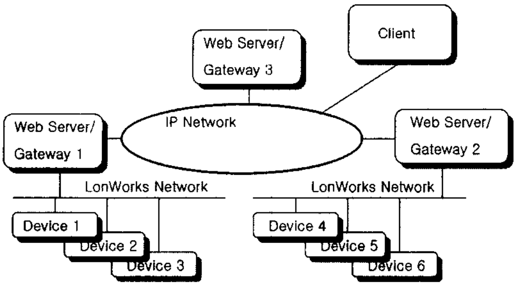

Fig. 3. LonTalk over Ip network realized in distributed server-client environment

6. Distributed Server-Client Model

Fig. 3 depicts the structure of distributed server-client model 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.

7. Example

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 DMCN 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.

An example of distributed monitoring and control functions for predictive maintenance was suggested in.[1] The open controller/monitoring function allows simple search for any alarm signal in the shared memory map in Fig. 5, 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 in Fig. 6 uses the address tables of the nodes being monitored that needs to be updated if any change has been made. The ad-

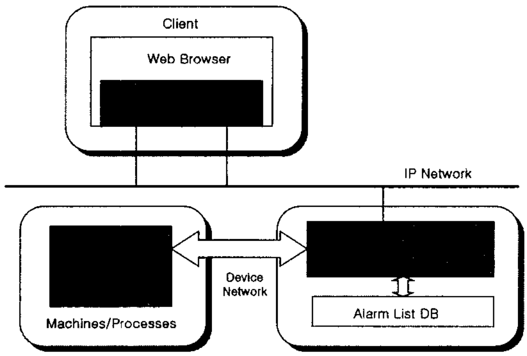

Fig. 5. Typical shared memory map method to retrieve data in the network

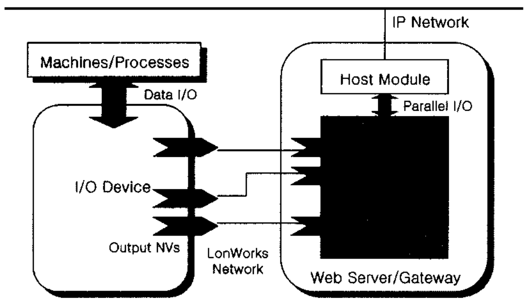

Fig. 6. Binding of the network variables between web server and LonWorks devices

vantage of using bound connection is that network variables are only updated when the data changes, reducing the unnecessary network traffics.

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. Fig. 6 shows how an input network variable is bound to an output network variable in other node.

In general, web-based diagnosis module uses monitoring functions to identify the abnormalities of the machines or uses inferring fault diagnosis module that detect other abnormalities that are not supported by the sensor signals. These informations then need to be further processed to be used for predictive maintenance purpose. Specifically, informations from sensors attached on machines and PLCs are fed into the knowledge-based expert systems where inference on the state of machines and processes are made.

8. Summary and Conclusion

A basic concept that can be applied to web-based monitoring and control over IP network was suggested. Specifically, LonWorks technology was considered as device (fieldbus) network. Connecting these remote LonWorks networks to the IP network can provide a powerful, integrated, distributed monitoring and control performance. Using the Device network over the internet by a number of users inherently involves a problem of security.[11] In other words, an unauthorized user can obtain manufacturing resources by breaking into the fire wall. Damage to the manufacturing and maintenance database will certainly affect the performance of VMS. Even such an occasion may cause the malfunction of the machines, which may significantly reduce the productivity.

Another problem area in the course of implementing VMS is the safety issues arising from the human-machine interface. Despite the highly automated manufacturing environment, manual operation by skilled workers is frequently needed for predictive maintenance. Company-wide safety measures that can limit the external manipulation of the automated machines and processes over internet while in service therefore needs to be implemented. Future work therefore includes implementation of such security mechanism on distributed monitoring and control devices for real-time data collection and web-based tele-monitoring.

References

1) J. W. Seo and M. Kang, “A Study on the Fault Diagnosis in Web-based Virtual Machine,” Proc. KSPE Spring Conf., pp. 430~434, 2001.
2) J. Seltzer and J. Hertle, “Utilizing A Distributed Data Collection System to Perform Predictive Maintenance and Equipment Reliability Studies,” Proc. IEEE, pp. 175~179, 1999.
3) D. Gaw, “LonWorks over the Internet: Technical Issues and Applications,” Technical Note, Coactive Aesthetics, Inc., 1999.
4) G. Ulsoy and Y. Koren, “Control of Machining Processes”, *ASME J. Dynamic Systems, Measurements, and Control*, Vol.115, pp. 122~132, 1993.
5) O. Vahamaki, A. Allen and J. Gaff, “High Speed Peer-to-Peer Communication System for Integrated Protection and Control in Distribution Network,” *Development in Power System Protection, IEE*, pp. 243~246, 1997.
6) H. Shahnasser and Q. Wang, “Controlling Industrial Devices over TCP/IP by Using LonWorks,” Proc. EEE, pp. 1309~1312, 1998.
7) Motorola, LonWorks Technology Device Data, 1996.
8) Motorola, *LonWorks Technology Device Data*, 1996.
9) Echelon, “Parallel IO,” Engineering Bulletin, 1999.
10) H Reiter, C. Kral, “Interaction Between JAVA and LonWorks,” *Proc. IEEE*, pp. 335~339, 1997.
11) S. J. Lim, K. T. Park and J. Lyou, “Realization of a Web-based Remote Monitoring Server for SMD in Line System,” Proc. KSPE Spring Conf., pp. 529~532, 2001.