예지보전을 위한 LonWorks/IP 가상 디바이스 네트워크의 통신특성에 관한 연구

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Transmission Characteristics in LonWorks/IP-based Virtual Device Network for Predictive Maintenance

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Abstract : Web-based predictive maintenance (PM) utilizes Virtual Device Network (VDN). VDN inevitably involves the implementation of Distributed Monitoring and Control Networks (DMCN). 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 investigates the transmission characteristics of VDN and suggests a basic framework for web-based PM using DMCN over IP network.

초 록 : 웹기반 예지보전 (Predictive Maintenance)은 가상 디바이스 네트워크를 필요로 한다. 가상 디바이스 네트워크는 반드시 분산형 감시 및 제어 네트워크를 통해서만 구현될 수 있다. 일반적으로 분산형 감시 및 제어 네트워크를 인터넷 상에서 구현하려면 TCP/IP와 필드버스 프로토콜의 통합이 필요하다. 이 경우, 예지보전의 성능을 극대화하기 위해서는 기기간의 통신 호환성이 절대적으로 필요하다. 본 논문에서는 가상 디바이스 네트워크의 통신 특성을 분석하고 이를 토대로 분산형 감시 및 제어 네트워크를 활용한 웹기반 예지보전의 기본 틀을 제시한다
Key Words : DMCN , virtual device network (VDN), LonWorks, predictive maintenance(PM)

1. Introduction

Recently, needs for access to the device/equipment information from several locations or anywhere in the enterprise is increasing. One example is the web-based predictive maintenance (PM) which utilizes virtual device network (VDN). In this configuration, predictive maintenance can be 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 include monitoring and control for diagnosis and remedy action in realizing preventive maintenance.

Web-based predictive maintenance 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 inter-operable DMCN can be justified in this sense.

Requirements for monitoring and control networks

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are different in many aspects from those of data networks[3]. Sending small packets over IP, for example, will decrease the efficiency of the IP network in terms of actual application data throughput as a proportion of overall network bandwidth. IP is, therefore, ill-suited for control networks and a gateway approach needs to be implemented to leverage the advantages of both control networks and data networks. Gateways can be used to provide data access to control networks from other than fieldbus protocol. Gateway approach has the advantage of being able to provide connectivity to the control network in a form that is more convenient for the upper level application. 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 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.

There are 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. VDN can take advantage of these capabilities by properly interconnecting the device network with data network components. Interoperability between devices and equipments is, however, essential to enhance the quality and the performance of predictive maintenance (PM)[4,5].

In this study a basic framework for VDN using DMCN over IP network for predictive and preventive maintenance is suggested. The transmission characteristic of VDN is investigated. A method to guarantee interoperability between devices is also suggested.

2. LonWorks/IP Network as a VDN

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[6]. There are numerous fieldbus systems available today. These include BACnet, CAN, CEBUS, IEEE-488, ISP, Interbus, Profibus, DeviceNet, LonWorks, WordFIP, etc

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 its interoperability and intelligent/distributed nature[7].

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 networks 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 VDN. The VDN includes remote sites connected with monitoring/control applications located on the IP networks.

Fig. 1 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.

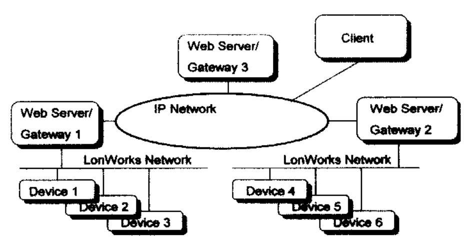

Fig. 1. VDN realized in distributed server-client environment using LonWorks/IP network.

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.

3. Transmission Characteristics OF VDN

In web-based DMCN effective predictive maintenance is possible only when the transmission delay is reasonably small and it can be compensated for. Thus, the characteristics of transmission delay on the VDN have to be known for successful implementation of DMCN. 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[9]. In this model, server uses CGI (Common Gateway Interface) functions to interface with database and expert system if necessary. Platform independent 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. 2 depicts such a structure.

The transmission delay in a data network is known to have a Gaussian distribution for transmission through long distances. For the cases of transmission through relatively short distances or transmission through many routers it is known to take the Gamma or exponential distribution[8]. However, the transmission delay in the VDN combines data network and device network should be more complex. In fact, the transmission characteristics of the integrated form oftwo different kinds of networks have rarely been investigated.

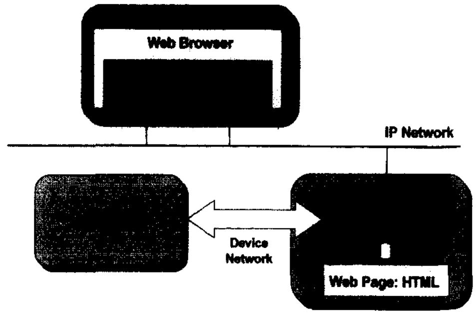

Fig. 2. Usage of JAVA applet in VDN.

In order to study the transmission characteristics of the VDN, the round trip time (RTT) between 2 devices connected to the device network were measured, and compared with those between a device on the device network and a client on the data network. Specifically, the client sends the sinusoidal signal expressed in 32 bit floating point numbers to the web server/gateway, and then the signal is passed to a LonWorks device on the device network. After receiving the signal from the web server/gateway, the LonWorks device sends the signal back to the client via web server/gateway. As the signal is returned to the client, it calculates RTT, and the same procedure is repeated. A Visual Basic program was written and used to measure RTT in the device network, while a client program was written in the form of JAVA applet to measure RTT between the device network and data network.

Figs. 3-5 show the results of round trip transmission experiment from the data network to the device network, and then back to the data network. The transmission characteristics is closer to Gaussian distribution rather than gamma or exponential distribution. It, however, seems to show both distributions in nature. This is because the transmission delay arises not only from the network channel but also from the calculation time for protocol conversion on the web server/gateway. It gives the network a transmission effect that occurs when there are many routers on the network. The delay is considerably larger. It takes time for the gateway to convert the web variable to the LonWorks network variable and to convert the LonWorks network variable to the web variable.

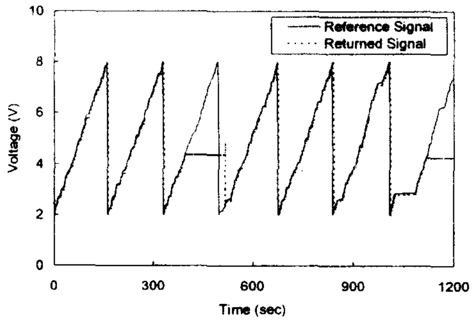

Fig. 3. The reference signal and the returned signal in round trip data transmission from data network to device network, and then back to data network.

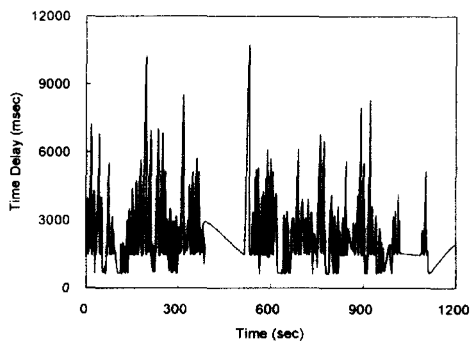

Fig. 4. Variation of RTT in round trip data transmission from data network to device network, and then back to data network.

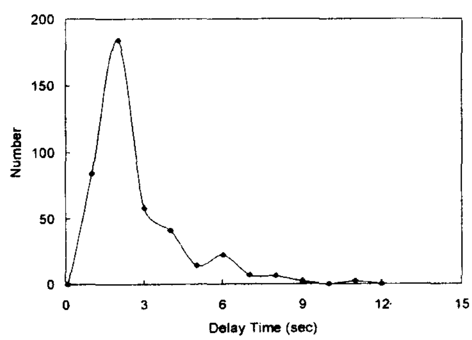

Fig. 5 Distribution of RTT in round trip data transmission from data network to device network, and then back to data network.

4. Application to Equipment Effectiveness Evaluation

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. Fig, 6 shows an example of equipment utilization evaluation in predictive maintenance application.

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 real-time 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 in Fig. 7 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.

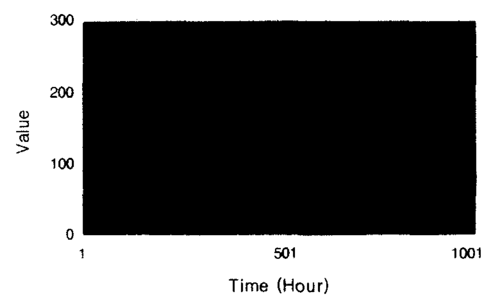

Fig. 6. Example of "Equipment Utilization Evaluation" for predictive maintenance.

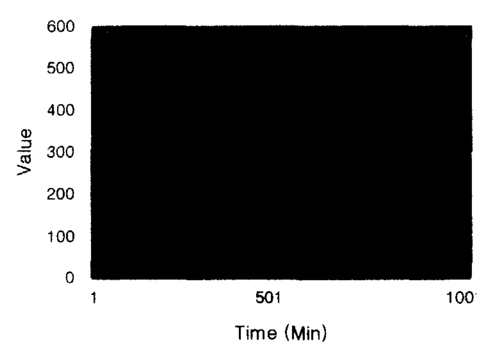

Fig. 7. Example of "Send-on-delta" method in predictive maintenance application.

5. Application to Equipment Reliablity Evaluation

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, information on how frequently alarm, alert and control limit conditions have occurred. This information is 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.

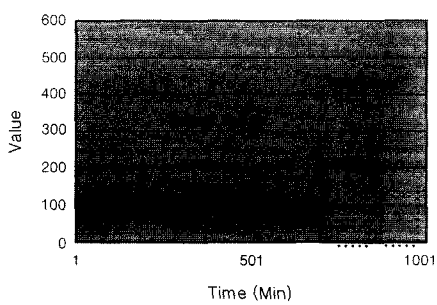

Fig. 8. Example of "Heart-beat" method applied to "Equipment reliability Evaluation".

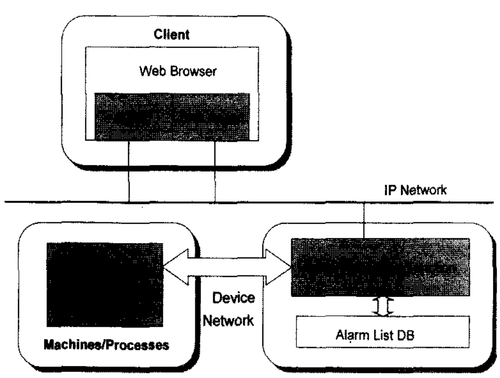

Fig. 9. Typical shared memory map method to retrieve data in the network.

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. 9, 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 use the address tables of the nodes being monitored that need 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.

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.

6. Conclusion

A basic concept that can be applied to web-based predictive maintenance using VDN 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. The transmission characteristic of VDN is also investigated for efficient DMCN. It seems to show both Gaussian and Gamma distributions in nature. This is because the transmission delay arises not only from the network channel but also from the calculation time for protocol conversion on the gateway. 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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