Transmission Characteristics in LonWorks/IP-based Virtual Device Network (VDN)

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Abstract

Web-based virtual machine/manufacturing system (VMS) utilizes Virtual Device Network (VDN.) VDN inevitably involves the implementation of Distributed Monitoring and Control Networks (DMCN). In general, one needs to integrate device (control) network and IP network to realize DMCN over IP network or internet, which can be viewed as a VDN. In this study, LonWorks networking technology is used for device network and the transmission characteristics of LonWorks/IP-based VDN is investigated. A method to minimize the transmission delay in the LonWorks/IP networks is also suggested.

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 virtual device network (VDN) [1]. Typical functions of such a system include monitoring and control for diagnosis and remedy. Internet access is also increasingly available and affordable, and along with the "internet" is the backbone of modern enterprise data networks.

With the increasing use of local area data network such as Ethernet in the enterprise, it became a convenient means to access device (control) network for data analysis and storage, and for monitoring and control functions. Requirements for monitoring and control networks, i.e., device networks, 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 device 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.

There are some common requirements between device and data networks. Examples are security, reliability, and flexible wide-area and remote access. 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 VDN.

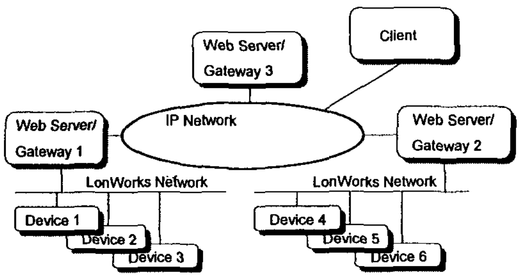

Fig.1 VDN realized in distributed server-client environment using LonTalk/IP network.

This paper investigates the transmission characteristics of LonWorks/IP-based VDN and suggests a method to minimize the transmission delay in the LonWorks/IP networks.

2. 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 integrating (remote) device network with business networks via the internet. By connecting device network via IP, multiple sites can be simply integrated into a seamless VDN [4,5]. The VDN includes remote sites connected with monitoring and 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. LonWorks over IP (LonWorks/IP) network utilizes a web serve with both Ethernet and LonWorks connection using a LonTalk over IP gateway [4,5,6,7].

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 LonWorks network variable from LonWorks network. The server then sends it to IP network using Ethernet connection or vice versa. In the client sites, the client will read it out and send back the related control command through network variables.

3. LONWORKS NETWORK AS A DEVICE (CONTROL) NETWORK

VDN 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.

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 [5].

Fig.2 shows the device network system composed of intelligent sensors and actuators. The distributed system is logically segmented by function, to allow a modular implementation. 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.

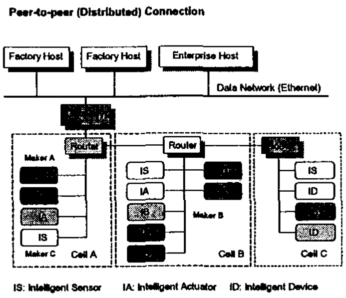

Fig.2 LonWorks-based intelligent/distributed (peer-to-peer) network.

4. TRANSMISSION CHARACTERISTICS OF VDN

Web-based VDN using DMCN is realizable only if the transmission delay is reasonably small. Otherwise, it needs to be compensated for in an appropriate way. This suggests that the characteristics of transmission delay on the LonWorks/IP network VDN have to be known a priori for successful implementation of VDN.

The transmission delay in a data network is known to have a Gaussian distribution for transmission through long distances. The transmission delay through relatively short distances or through many routers is, however, known to have the Gamma distribution [6]. The transmission delay in the VDN that combines data network and device network, therefore, appears to be more complicated. Accordingly, the transmission characteristics of the integrated form of two different networks have rarely been investigated. In order to evaluate the transmission characteristics of the VDN, the unidirectional transmission time (UTT) between a device on the LonWorks network and a client on the IP network has been be measured and analyzed in this study.

5. MEASUREMENT OF UTT

UTT was measured in two ways. First, it is attempted to calculate the UTT when the signal is sent from LonWorks device (analog input interface module) to the client (PC) on the IP network. Specifically, the client on IP network sends the reference signal expressed in 32 bit floating point numbers to the gateway, and the signal is subsequently passed to a device on the LonWorks network. When the signal arrives at the LonWorks device, UTT was calculated. UTT based on the backward transmission, i.e., the transmission originating from LonWorks device to the client on the IP network was also calculated.

UTT in the LonWorks network was measured using a LonWorks Network System (LNS) plug-in program. For this purpose, a Visual Basic program was written to measure the transmission time in the LonWorks network, while a client program was written in Java applet to measure the transmission time between the LonWorks network and IP network. Fig.3 depicts the block diagram of the structure of data transmission on the LonWorks/IP network.

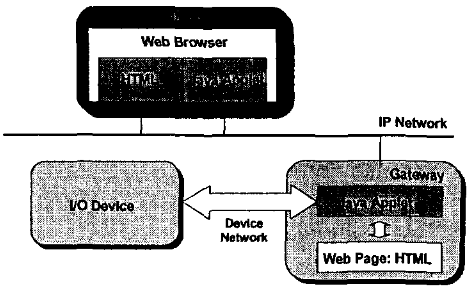

Fig. 3 The structure of data transmission on the LonWorks/IP network using Java applet in VDN environment.

6. RESULTS AND DISCUSSION

The result of unilateral data transmission experiment from IP network to LonWorks network when the client on the IP network and the device on the LonWorks network are separated within a short distance (within a few meters) is shown in Fig.4. Fig.4 compares the signal received by the LonWorks device with the sinusoidal reference signal of the client. The distortion of the received signal is mainly due to the inherent time-varying transmission delay.

It was found that the delay in the LonWorks network was negligible. The randomness of UTT shown in Fig.4 is, therefore, mainly due to the random transmission delay of IP network. The distribution of UTT is shown in Fig.5. As expected, the figure indicates the characteristics of both the Gaussian and the Gamma distributions. Both the network channel and the protocol conversion in the gateway appear to contribute to the time delay in this case.

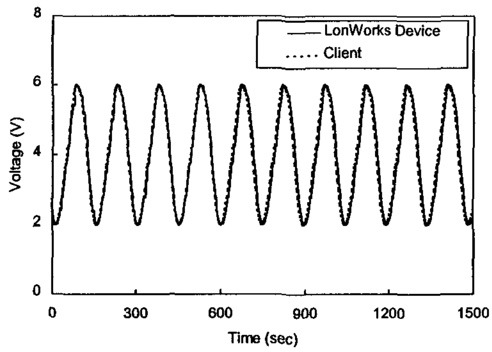

Fig.4 Comparison of the sinusoidal reference signal of the client and the received signal of the LonWorks device in unilateral data transmission from IP network to LonWorks network.

The protocol conversion from IP network to LonWorks network performed in the gateway is responsible for about 250 *msec* of transmission delay. Most of the delay stem from the mapping between the web variables and the network variables of LonWorks network. Therefore, in order to minimize the transmission delay, an efficient variable mapping algorithm needs to be implemented.

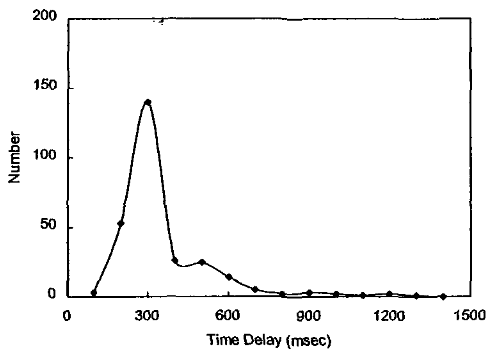

Fig.5 Distribution of UTT in transmission from the client on the IP network to aa device on the LonWorks network.

Unilateral data transmission experiment from LonWorks network to IP network was also performed. The sinusoidal reference signal of the LonWorks device and the received signal of the client are compared in Fig.6, while the distribution of UTT is shown in Fig.7. Compared to the results in Fig.4 and Fig.5, longer delays are clearly seen in the figures. This is because the data transmission is initiated when the client on IP network asks the gateway to send the data, and then the data is transferred from the device to the client through the gateway, while in the case of data transmission from IP network to LonWorks network the client can write the data directly to the device through the gateway.

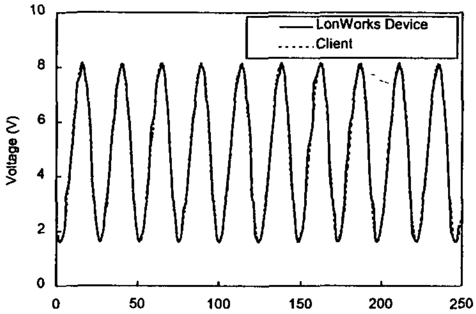

Fig.6 Comparison of the sinusoidal reference signal of the LonWorks device and the received signal of the client in unilateral data transmission from LonWorks network to IP network.

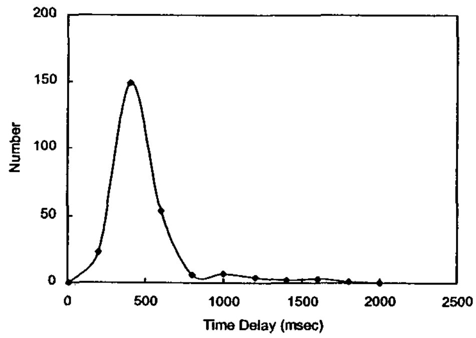

Fig.7 Distribution of UTT in transmission from LonWorks network to IP network.

6. CONCLUSION

In this study, a basic framework that can be applied to VDN using distributed monitoring and control over IP network was suggested and the related transmission characteristics of VDN were experimentally evaluated. Specifically, LonWorks network technology was considered as device (control) network. Connecting the remote LonWorks devices to the IP network can provide a powerful, integrated, distributed monitoring and control performance. The unidirectional transmission time has been evaluated and the major factors that affect the transmission performance have been identified. Most of the delay stem from the mapping between the web variables and the network variables of LonWorks network. Therefore, in order to minimize the transmission delay, an efficient variable mapping algorithm needs to be implemented.

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