철도차량용 LonWorks/IP 가상 디바이스 네트워크 (VDN)에서의 실시간 분산제어

Real-time Control on LonWorks/IP Virtual Device Network(VDN) for Rail Transit Vehicles

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Abstract: A general idea of implementing and managing real-time control on the VDN for rail transit vehicles is presented. In particular, the virtual device network considered in this paper is composed of Ethernet as the data network and LonWorks network as the device (control) network. A LonWorks/IP web server was used as a gateway to realize peer to peer data communication on the virtual device networks. Experimental results are given to validate the suggested architecture.

Key Words: LonWorks, Device Network, Data Network, Rail Transit Vehicle, 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 rail transit vehicle. One example is virtual machine system (VMS), which utilizes VDN [1]. In this configuration, monitoring and control can be performed both on local floor and in remote site through IP network [2]. 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 [3].

Requirements for monitoring and control networks are different in many aspects from those of data networks [4]. 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.

The objective of this study is to suggest a basic framework for implementing and managing real-time control on the VDN for rail transit vehicles using LonWorks/IP web server in a VMS environment.

2. MANAGEMENT OF VIRTUAL DEVICE NETWORK (VDN)

2.2 LonWorks as Rail Transit Vehicle Network

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. Using fieldbus as a means of industrial communication has several advantages:

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

Among many available fieldbus protocol, LonWorks was chosen as the device control network for several reasons in this study. The most significant ones are as follows:

- 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.

- 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.
- 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.

Application of fieldbus to rail transit communication was summarized by IEEE 1473-1999 standard. This standard specifies interfaces among heavy rail cars, light rail cars and commuter rail cars. The key features of IEEE 1473-1999 rail transit vehicle network standard are summarized as follows [5]:

(1) 1473-T (TCN)

- It is relatively new, dedicated and special purpose technology
- It uses closed and proprietary architecture.
- This standard is used by some railcar builders in Europe such as Adtranz, Siemens, and Ansaldo Consortium

(2) 1473-L (LonWorks)

- It is well-established and general purpose networking technology
- It uses open architecture (open protocol)
- Used in many railcar procurements such as Adtranz, Alstom, Bombardia, Kawasaki and CAF

Fig.1 shows the typical example of IEEE1473-L network interface in an application to rail transit communications.

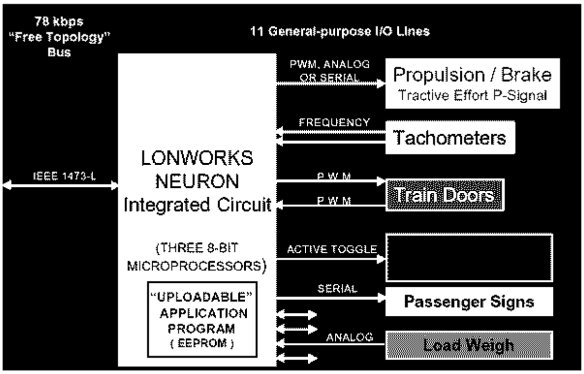

Fig.1 IEEE 1473-L interface [5]

2.2 Implementation of VDN

Fig.2 shows the typical architecture of train communication system. By integrating device (control) network with IP network, however, the IP network can be used for distributed control of a remote system. By connecting device network with IP network, multiple sites can be simply integrated into a seamless "Virtual Device Network" (VDN) [2]. The VDN includes one or more remote sites connected with one or more monitoring/control applications located on the IP network. The general architecture of a VDN is shown in Fig.3. The key concept to this architecture is the peer-to-peer communication, from device 2 to device 5, for example. It is also possible to monitor and control the peer devices on a remote site (client PC) through the LonWorks/IP web server (dotted line in Fig.3).

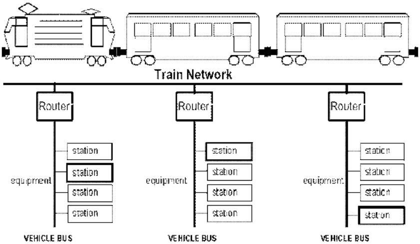

Fig.2 Typical architecture of train communication system [5].

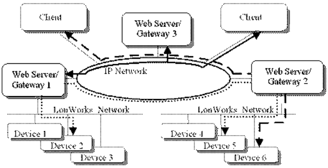

Fig.3 VDN realized in distributed server-client environment using LonWorks/IP Gateway/Web server.

2.3 LonWorks/IP routing by peer to peer network variable binding

VDN is constructed by several local device networks connected to the data network through the LonWorks/IP web server. LonWorks network devices comprise a local LonWorks network along with a LonWorks/IP web server which is a member of the data network. A LonWorks/IP web server offers the information of the network variables of the local LonWorks network devices. An authorized user or a VDN manager can access a local LonWorks network through a LonWorks/IP web server and connect it to the other LonWorks/IP web server in the network [6].

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

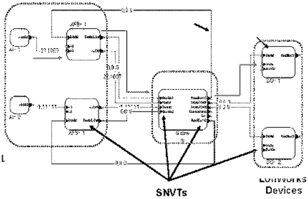

Fig.4 Network variable binding of the LonWorks network devices used for one-to-one communication.

Fig.5 shows the web page for peer to peer network variable binding through a LonWorks/IP web server. In general, LNS application software is needed to bind the network variables among different networks. A LonWorks Network Server (LNS) application program in the remote client PC interacts with the Microsoft's embedded Windows OS (Operating System) installed in the LonWorks/IP web server through data networks. This LNS application program is needed using a LNS application program development tool from Echelon Corporation. The LNS application program enables an exchange of data/information between the individual devices within the network and manages virtual device networks in operation. Using this application utility, one can monitor and control an individual "peer" device either on a remote place or on an another peer device. The LonWorks/IP web server, which connects the data networks to the device networks, is required in order to manage virtual device networks in this fashion [6].

The suggested method, however, gives a simple and useful peer to peer routing for small scale remote monitoring and control applications. Furthermore, the routing using LNS needs a centralized management of the network data base on the server, which is less user-oriented. On the other hand, the proposed routing method enables use of distributed network information storage, and is more user-oriented. In this case, the local device network still needs to be configured with LNS in advance.

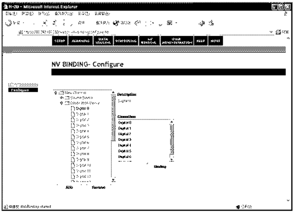

Fig.5 Peer to peer network variable binding on a LonWorks/IP web server supplied web page.

2.5 Security Issues

LonWorks/IP data transmission is performed by the tunneling technique which is the core part of EIA/CEA-852 standard established by CISCO and Echelon. Fig.6 depicts a security check logic described in this tunneling standard. A tunneling technique encodes the communication packet of LonWorks including address information device networks as well as the network variable binding information into the data packet of an IP protocol. Data (LonWorks packet) and the 128 bit secrete word are then encoded using MD 5 algorithm to construct an IP packet. This packet is transmitted to the receiving LonWorks/IP web server where the decoding process is performed. The receiving LonWorks/IP web server first encodes the transmitted data with its own 128 bits secrete word to check if the packet is from the authorized web server. Once the security check is passed, it transmits the LonWorks data to the destination device on the lower device network according to the NV binding information it received. A LonWorks/IP web server on virtual device networks becomes a connection pass, which can transmit and receive the data/information of device networks safely in this method.

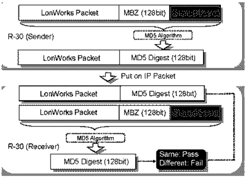

Fig.6 MD 5 authentication as specified by EIA/CEA 852 LonWorks/IP tunneling standard.

3. EXPERIMENTS AND RESULTS

Fig.7 shows that the experimental set up on VDN where VDWorks' Distributed Control Modules (LonWorks devices) DI-20, AI-20, AO-20 and IS-30 LonWorks/IP Web Server were used. DC servo motor system by ED engineering was used as the plant.

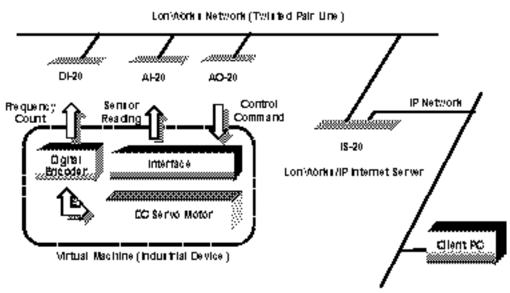

Fig.7 The experimental set up of the DCS on VDN

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 [6]. The transmission delay in the VDN combines data network and device network should be more complex. There was a study on the transmission delay in the VDN through the round trip transmission experiment from the data network to the device network, and then back to the data network [7]. The transmission is more likely to have Gaussian distribution rather than gamma or exponential distribution. This is because the transmission delay is not only due to the network channel but also due to the calculation time required for protocol conversion on the web server/gateway.

The transmission characteristics on internet and on VDN were investigated through the real time distributed control in [8]. Long transmission delays were intermittently observed due to the inherent transmission characteristics of the internet. It takes effects on the transmission characteristics of the VDN. In fact, the considerably long transmission delay of VDN observed is mainly due to the transmission characteristics of IP network.

Table 1. Distribution of transmission delay on internet

Time Delay (ms)	Remote site(counts)	
	Send	Receive
< 100	101	70
100 - 1000	904	941
1000+	18	12

For the case with time delay, compensation of adverse effects coming from the network delay is necessary for successful implementation. In this study, Smith's predictor was used [9, 10]. The main advantage of this technique is that the time delay can be eliminated from the characteristic equation of the closed loop system. Thus, the design problem for the process with delay can be transformed to the one without delay. Fig.7 shows the block diagram of proposed control structure utilizing the Smith's predictor.

Fig.8 show the results of both the traditional PI control and the PI+Smith's Predictor-based control on step reference tracking application [10]. In the figures, the performance of LonWorks/IP Web Server is shown to be acceptable in terms of the time delay involved in the network transmission.

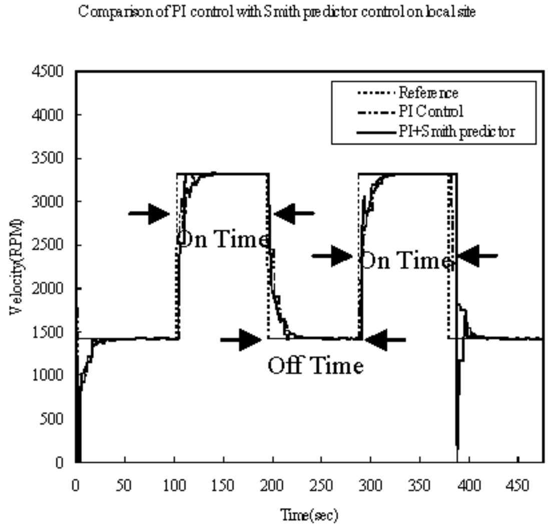

Fig.8 Comparison of PI control with Smith predictor-based control for step reference input on local site.

4. CONCLUSIONS

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. The suggested virtual network management system enables an access to the information on the local LonWorks device from the remote place. Connecting these remote LonWorks networks to the IP network can provide a powerful, integrated, distributed monitoring and control performance. This paper suggested the method of VDN management, particularly aimed at implementing VMS. Application of such VMS to rail transit vehicle was suggested as a model case. This means that operation, integration, and management as a whole can be performed in a efficient and productive way.

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