지하시설의 안전관리를 위한 LonWorks 네트워크의 유지보수에 적합한 프로토콜 분석기의 개발

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(2010. 4. 30. 접수 / 2010. 12. 10. 채택)

Development of Protocol Analyzer Suited for Maintenance of LonWorks Network for Safety Management of Underground Facilities

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(Received April 30, 2010 / Accepted December 10, 2010)

Abstract : A compact ANSI/EIA 709.1 protocol analyzer system suited for maintenance of LonWorks network for safety management of underground facilities was developed and tested. The hardware is based on the TMS320LF2406A embedded system, and the software was designed using Visual C++6.0 under Windows XP environment. Connected to the LonWorks network the developed protocol analyzer decodes the raw packets and pass them to the master PC through USB port. Then on the PC the packets are processed and analyzed in various aspects and the key features that are essential to the maintenance of LonWorks network installed at underground facilities are displayed in a user-friendly format. Performance of the developed protocol analyzer was evaluated through a series of experiments, by measuring the speed of packet analysis and the error rate. The protocol analyzer proved to work reliably even under the increased bandwidth. However, more comprehensive tests under various underground environmental conditions are desired.

초 록 : 지하시설의 안전관리를 위하여 설치된 LonWorks 네트워크의 유지보수에 적합한 작은 크기의 ANSI/EIA 709.1 프로토콜 분석기를 개발하고 테스트하였다. 하드웨어는 TMS320LF2406A 임베디드 시스템을 기반으로 하였고, 소프트웨어는 Windows XP 환경의 Visual C++6.0을 이용하여 설계하였다. 개발된 프로토콜 분석기는 LonWorks 네트워크에 연결되어 들어오는 패킷을 디코딩하고, USB 포트를 통하여 마스터 PC에 전달하도록 설계하였다. 그리고 PC에서 패킷이 처리되고, 여러 방법으로 분석되어 지하시설에 설치된 LonWorks 네트워크의 유지보수에 필수적인 정보를 담고 있는 중요변수가 관리자에게 편리한 형태로 화면에 나타나도록 하였다. 프로토콜 분석 성능은 일련의 실험을 통하여 패킷분석의 속도와 에러율을 측정함으로써 평가되었다. 개발된 프로토콜 분석기는 밴드폭 이용이 크게 증가하는 경우에도 안정적으로 동작하였다. 그러나 다양한 지하 환경조건 하에서 좀 더 종합적인 테스트도 필요하다고 생각된다.
Key Words : fieldbus, LonWorks, protocol analyzer, safety management

1. Introduction

In September 8, 2006, there was a CO(carbon monooxide) gas leaking accident at Jonggak subway station of the Seoul Metro Line #1(Fig. 1). Highly toxic CO gas had been leaking from cooling/heating system undetected at the subway station for 3 days, and eventually 66 people are intoxicated and hospitalized. Also, the trains had to pass the station without stopping for an hour and 30 minutes causing chaos among citizens using the Metro. This accident clearly demonstrated the need for integrated air quality monitoring and safety management system for the Metro, and such a system that has particle(PM_{10}) sensor, CO_2

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sensor, CO sensor, and VOC(volatile organic compounds) sensor, as well as temperature and humidity sensors was developed and installed on most of the Metro stations, and is continuously being upgraded at huge expense of public money.

To achieve the goal of public safety by ensuring the proper operation of such an air quality monitoring and safety management system, integrated operation of the systems installed on all the stations is necessary, and therefore the system has to be based on fieldbus. Fieldbus means industrial communication network especially suited for real-time distributed monitoring and control in automated systems[1]. Many different fieldbus network standards for different applications are being used for communication between devices in large buildings and public facilities. The key feature of the fieldbus network in management of distributed control and automation system is reliability and flexibility[2]. Among several fieldbus network standards, LonWorks not only provides the reliability and flexibility that most systems require, but also is commercially available in chips based on widely used ANSI/EIA 709.1 open protocol. In addition, LonWorks provides the common application framework using the concept of network variable and standard network type[3-6].

In practice, the reliability of such fieldbus based systems can be guaranteed by checking the network operation regularly, and at any time checkup is needed. LonWorks Protocol analyzer is a device that can be used for real-time analysis of data travelling through the LonWorks network when it is connected to the network. In many applications of LonWorks technology including distributed monitoring and control in large buildings and public facilities, LonWorks protocol analyzers are necessary for checking proper operation and eventually for improved reliability of the network[7,8].

In this study a real time ANSI/EIA 709.1 protocol analyzer especially suited for maintenance of LonWorks network installed in underground facilities was developed. First, imbedded system based compact protocol analyzer hardware was developed. Then the application program for sending decoded data to PC through USB port and processing the data to extract and display the key features of the data was developed with Visual C++6.0 under Windows XP environment. Finally the packet processing experiment was done, and the speed of packet analysis was measured.

Fig. 1. Photo of CO(carbon mono-oxide) gas leaking accident at Jonggak station of the Seoul Metro Line #1 (September 8, 2006).

2. Use of Ansi/Eia 709.1 Protocol for Remote Monitoring and Control

Fieldbus was introduced as a method of communication between controllers, sensors and actuators for industrial monitoring and control. As the demand for industrial communication network that supports real-time communication increases, and as the open type controllers became widely available, fieldbus became a key factor in industrial automation systems. Centralized control structure where several control devices are connected to a single controller usually has the

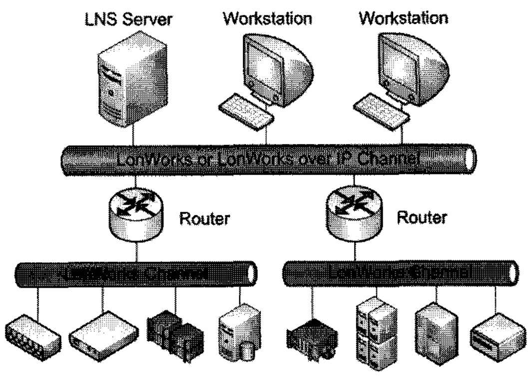

Fig. 2. An example of distributed control system structure (VDN) based on LonWorks and IP network.

star topology. This structure is vulnerable to errors, and expansion or modification of the system is not usually easy. With application of fieldbus these problems can be avoided. It solves wiring problem using bus topology and makes system expansion or modification easy by providing the same interface for all the devices. There are more than 40 fieldbus standards available today, including Profibus, DeviceNet, BAC net, and LonWorks. Among many available fieldbus standards LonWorks technology is widely accepted in the building automation industry for implementing distributed control system(DCS). LonWorks protocol is based on the ANSI/EIA 709.1 control network standard, and ANSI/EIA 709.1 protocol is based on the ISO/OSI Reference Model.

In such applications as remote monitoring and control access to the device/equipment information from any local or remote location is important. If device networks are connected to IP network, multiple sites/locations can be simply integrated into a seamless "Virtual Device Network"(VDN)[9,10]. Fig. 2 shows a LonWorks based VDN structure. In this structure end devices are connected to the LonWorks network, and the LonWorks network is connected to the IP network through the router forming the VDN. The VDN proved to be effective in monitoring and control for diagnosis and remedy action in management of indoor air quality in the subway stations[11-13].

3. Implementation of the Protocol Analyzer Hardware

Fig. 3 shows the protocol analyzer board developed in this study. Ports for twisted pair lines on the left are for LonWorks input signal, while the USB port is on the right of the board. On the board FT-X1 transceiver and TMS320LF2406A DSP CPU are installed. It was made very compact (10cm wide including input and output ports, 4cm high, and 2cm deep), considering the fact that portability is very important in carrying out maintenance job in underground environment. Fig. 4 illustrates the connection of the protocol analyzer. It is connected to ANSI/EIA 709.1 LonWorks network using twisted pair lines, and connected to notebook PC using the USB port.

The protocol analyzer was designed to receive data signal from TP/FT-10 type, twisted pair channel, and the data coded in the LonWorks protocol is translated into differential Manchester code through the transceiver(FT-X1), and then passed to the MCU. The transceiver uses preamble bits to identify the beginning of new packet, and its transmission speed is 78.125 kbps. The signal from the transceiver is then changed to 3.3V binary level signal using the comparator, and then inverted before being fed to the TMS320LF2406A DSP. Fig. 5 shows an example of how the signal from the transceiver is changed as it passes through the comparator(LM319). About 80 ns of time delay between the input signal (1) and the output signal (2) of the comparator is clearly seen. The binary output from the comparator is sent to the inverter and then to the DSP for decoding. In the DSP, timer was set at 78.1kbps to match transmission speed of the transceiver. The DSP counts preamble bits to divide packets, and decoding is executed using the differential Manchester code.

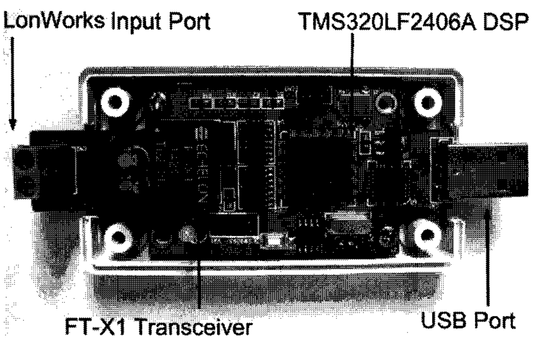

Fig. 3. Developed protocol analyzer board.

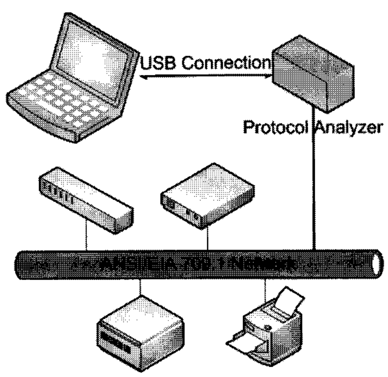

Fig. 4. Connection of the protocol analyzer.

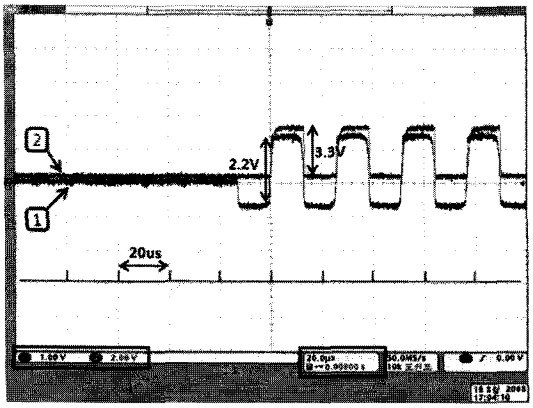

Fig. 5. Signal before and after the comparator.

4. Application Program on PC

Application program on PC was developed under Windows XP environment using the real time objective programming capability of the Visual C++ 6.0. Fig. 6 shows the overall flow chart of the application program. The process begins by checking the connection of the USB port. If there are packets to be processed, the data is received using the thread in real time. Then the packets are divided with the reference to the preamble bits, stored in buffer, and wait to be displayed on screen using another thread. Then, the packets are analyzed and checked for possible

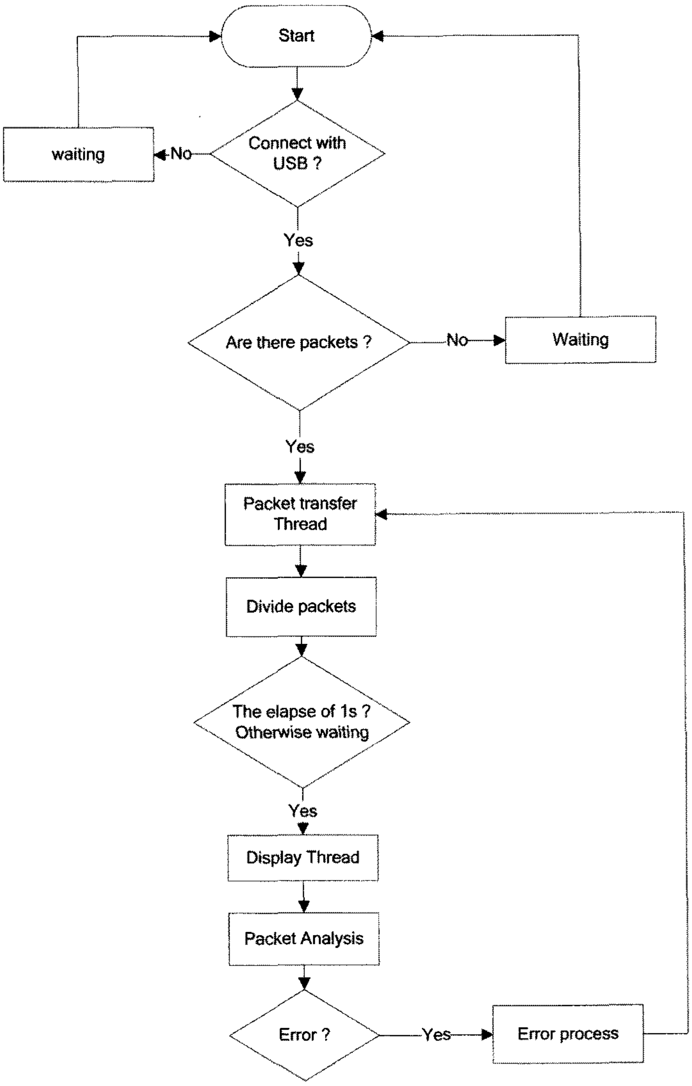

Fig. 6. Flow chart of the application program.

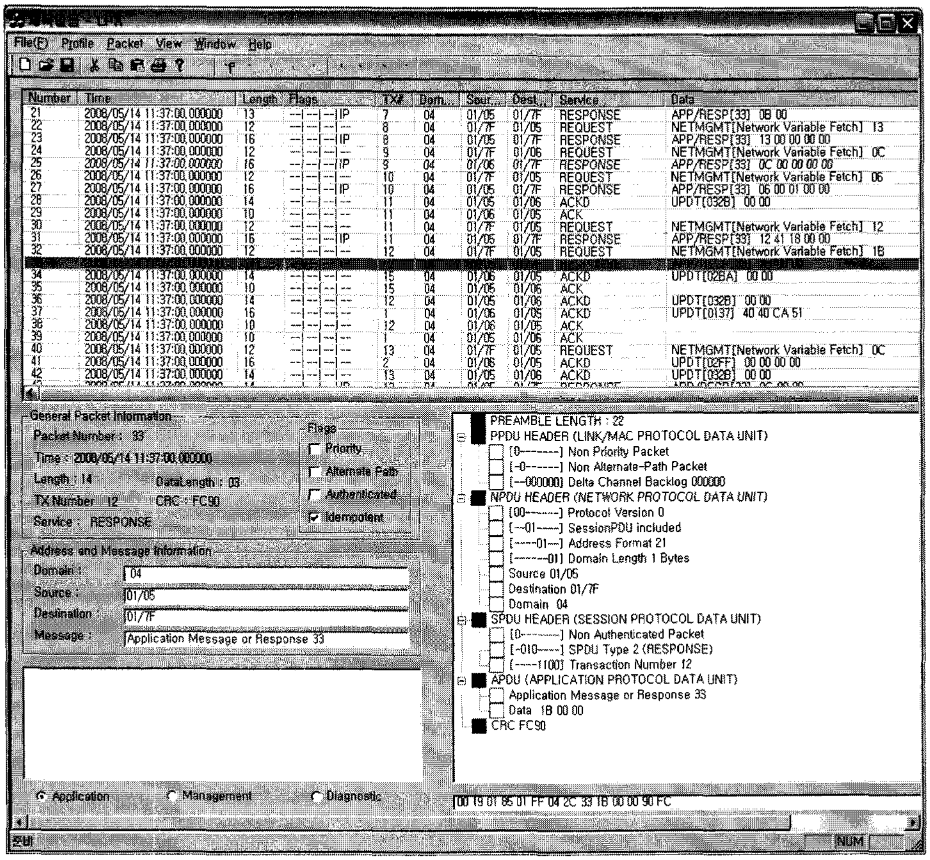

Fig. 7. Main screen display of the application program.

errors using the error processing algorithm. The results of analysis are displayed on the sections of the screen, and this cycle is repeated.

Main screen display of the application program is composed of packet table, packet details, and protocol details, as seen in Fig. 7. Specific portions of packet data can be displayed at each layer using the filtering function. If there are many problems in a message, only the message in the related layer is filtered excluding normal layers. This kind of filtering is helpful in finding and analyzing problems happening on the network. It also has the function of detailed statistical analysis of packets. Packets are analyzed at each layer and various statistical characteristic values are computed and displayed. Also, the composition of various message formats is calculated to estimate the network traffic. If the statistical value of a specific error is high, or a specific message happens frequently, then possible problems are immediately checked so that the relevant action can be taken.

5. Verification of the System

The developed protocol analyzer board was tested at a subway station. Connected to a master notebook PC it worked perfectly as a protocol analyzer system even under the harsh environmental condition of the subway station. Also, experiment for measuring the speed of packet processing was done. The packet traffic on the network was increased by shortening the update interval for network variables(NV), and the stability of the system was checked as the bandwidth utilization is increased. Actually, 50,000 data were analyzed repeatedly 5 times under various NV update time. The experimental results are summarized in Figs. 8-9. As the NV update time is decreased the rate of packet generation and bandwidth utilization increases, but the packet error rate was kept below

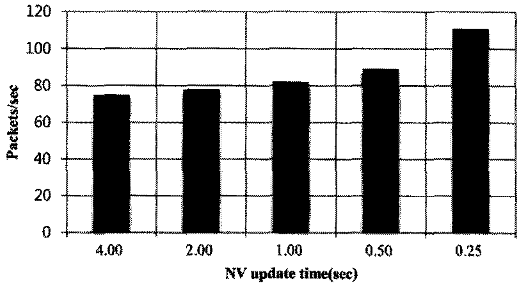

Fig. 8. Packet rate depending on NV update time.

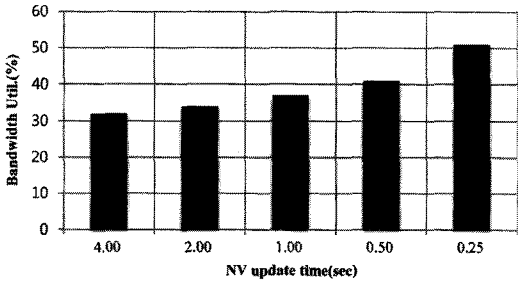

Fig. 9. Bandwidth utilization depending on NV update time.

2% which can be regarded as acceptable throughout the experiment. The bandwidth utilization was kept below 50% at the NV update time of 0.25sec. Even when the NV update time was made shorter than 0.25sec., the bandwidth utilization did not increase dramatically. It is due to the characteristics of LonWorks network that uses alternate paths rather than increasing the bandwidth utilization as the packet rate increases.

Algorithm for checking the packet error was devised as shown in Fig. 10. First of all, whether the packet has any error is test by checking CRC, and then the current position and the total length at each layer are compared to detect error condition. Bandwidth utilization is also checked, and if it is over roughly 50%, some kind of problem is highly possible. In that case cable connection is checked and the node that has high communication rate is identified. If the

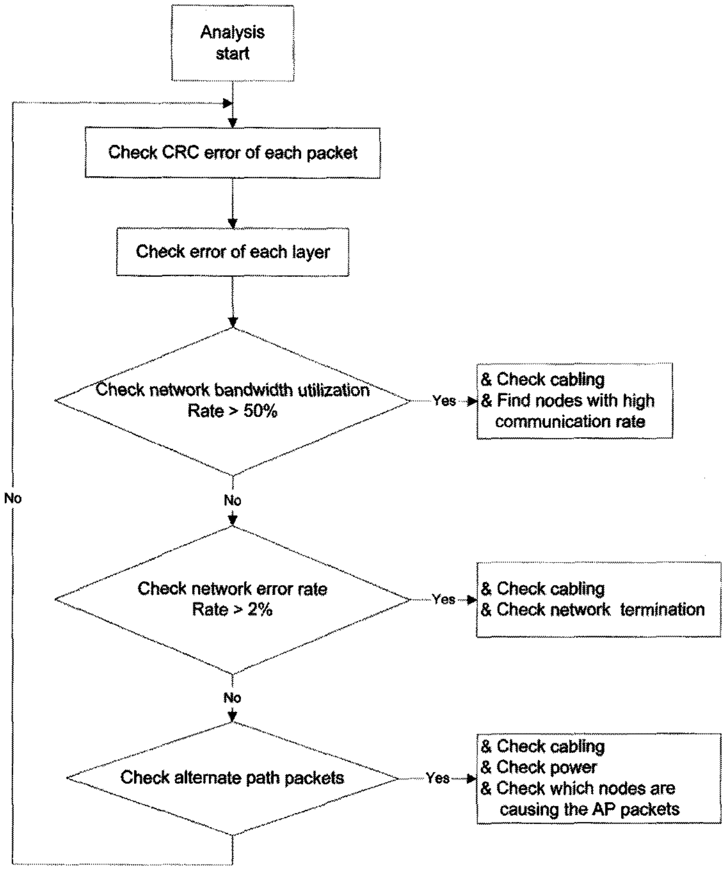

Fig. 10. Workflow chart for error process.

total error rate indicates that there is indeed a problem on the network, end devices are checked immediately. If a specific packet is sent several times through alternate paths, then only the related paths are checked to find the network error.

6. Conclusion

Effective maintenance of fieldbus network is crucial to safety management in public facilities like large buildings, factories, or subway stations. For this purpose detailed and customized information on network errors as well as simple packet information is necessary. Development of a compact LonWorks protocol analyzer system suited for such applications was done in this study. Specifically the protocol analyzer hardware and the corresponding application program were developed.

The developed protocol analyzer hardware was designed to decode the raw packets and pass them to the master PC for further filtering, statistical analysis and user friendly display of the key features representing network status. Also, processing algorithm for various kinds of packet errors was devised to improve the performance of the protocol analysis. The system achieved stable operation even under harsh conditions of underground facilities throughout the experiment. In practice, it can be used for checking the health of LonWorks network to prevent disaster that can happen as the LonWorks based safety monitoring system fails to work properly. However, more detailed experiments under different conditions are needed to achieve the high reliability level required for public safety management systems.

Acknowledgement

This work was supported by the University of Seoul 2009 Research Fund. The authors would like to express their gratitude for the financial support.

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