Design and Implementation of Network Management System for Power Line Communcation Network

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Abstract—**Power Line Communication (PLC) is an evolving communication network technology using the existing power lines and enables to provide the automatic meter reading service, high-speed Internet service as well as home networking service. As the use of PLC network and their applications increase, we need to manage the resources of PLC networks efficiently. Major PLC chipset and modem vendors are trying to provide network management solutions, but they are only specific solutions. It is necessary to provide a general PLC network management solution for PLC networks comprised of PLC devices from heterogeneous vendors. In this paper, we propose a PLC network management system called i-NetMSuite4PLC. We also propose a common PLC MIB (Management Information Base) based on some existing PLC MIBs. We present the design and implementation of the system.**

Keywords: PLC (Power line communcation), NMS (Network Management System), PLC MIB (Management Information Base)

I. INTRODUCTION

RECENTLY, power line communication (PLC) which uses the pre-installed power lines has received tremendous attention for access and home networking [1, 2]. Because the power line has been already installed every where, we are able to compose the target network easily and cost-effectively. PLC has been used to network indoors and homes, AMR (Automatic Metering Reading), remote control and monitoring system.

Like any other network, it is necessary to manage through monitoring and controlling the PLC devices and resources for efficient, reliable and secure operations. The PLC NMS (Network Management System) should provide five major functions for the network management such as FCAPS (Fault management, Configuration management, Accounting management, Performance management, and Security management). The PLC MIB (Management Information Base), which is the set of the managed objects for PLC devices, also should be defined to manage the PLC network appropriately. Further, the SNMP agent should be equipped to the devices and provide management information to the manager through the management protocol such as Simple Network Management Protocol (SNMP) [3, 4].

Currently, PLC network is composed of following four types of PLC devices: 1) devices using DS2 chip sets [5], 2) devices using Intellon chip sets [6], 3) devices using Xeline chip sets [7], and 4) devices using Panasonic[8]. Until now, DS2 and Xeline have defined PLC MIBs and have SNMP agent implemented in their devices. Intellon and Panasonic are currently working towards defining PLC MIBs based on their PLC chip sets. Typical PLC networks will likely be composed of PLC devices from multiple vendors, possibly developed using different chip sets. However, in order for SNMP manager to manage these heterogeneous devices, it is desirable to have a common and standard MIB defined and implemented in all of these devices.

In this paper, we present our work on defining a common PLC MIB. We have developed a PLC network management system called i-NetMSuite4PLC based on this common PLC MIB. This system is able to help the administrator to detect the PLC network faults, recover them, configure the network, and monitor the performance of the network. We have focused our development based not on any specific PLC device vendor but on general PLC network management using the common PLC MIB definition. And also, we have installed PLC devices and composed the small PLC network. We have tested our proposed system on it.

The remainder of this paper is organized as follows. Section II presents a brief overview of PLC network technology, a SNMP based network management, and PLC network management as related work. Section III presents the design of common PLC MIB. It also presents the design and implementation of our PLC NMS. Section VI presents the experimental result on the small PLC testbed. Finally, conclusions are drawn, and future work is discussed in Section V.

II. RELATED WORK

A. Overview of PLC Network

The PLC technology enables utility companies to deploy a communication network over existing power line infrastructures by transmitting data signals through the same power cables that transmit electricity [9, 10]. PLC can be divided into Medium Voltage (MV) PLC and Low Voltage (LV) PLC as shown in Fig 1. MV is 22.9 kV power line from the substation to the transformer. LV is 220V power line from the transfer to the home. There are different types of PLC

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devices to compose PLC network such as PLC master modem, PLC slave modem, and PLC repeater [11]. A MV master modem is a device used to connect the backbone network (such as fiber network, xDSL or cable network) and MV PLC. A MV Repeater is a device used to amplify the signal between MV PLC modems. A PLC slave modem is a device used to transfer the signal between transformer and home devices.

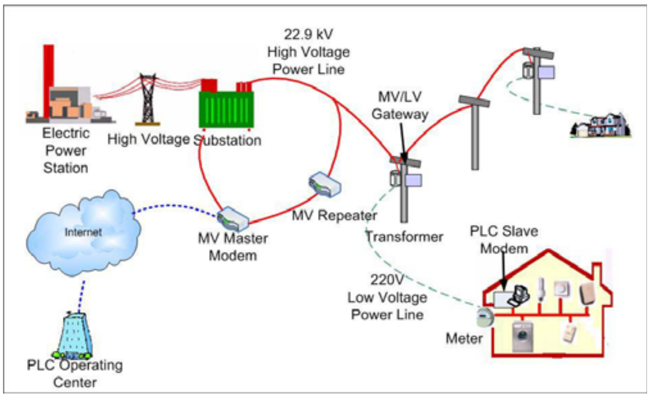

Fig 1. Overview of PLC Network Architecture

B. SNMP based network management

SNMP is the most widely used method for network management on the Internet and on enterprise networks that use IP and has been standardized by the Internet Engineering Task Force (IETF) [12]. The SNMP-based network management is based on the manager-agent paradigm as shown in Fig 2 [3]. The SNMP manager provides the interface to the network manger to monitor and control the network. And, it interacts with SNMP agent through SNMP. The SNMP agent is equipped in the managed device and responds to requests for information and actions from the SNMP manager.

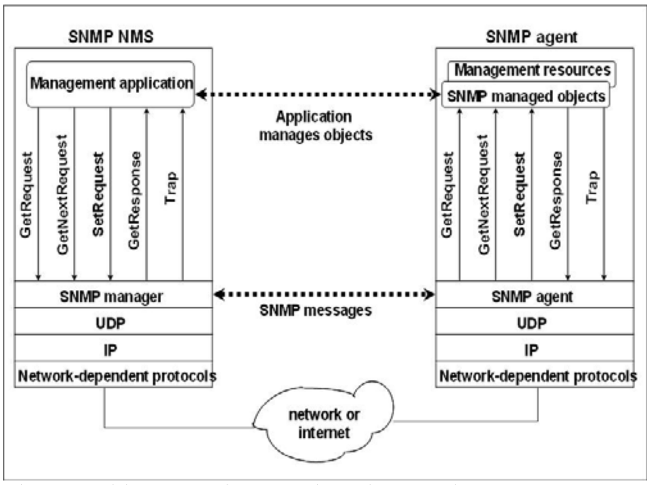

Fig 2. Architecture of SNMP-based network management

Resources in the network may be managed by representing these resources as objects. Each object is, essentially, a data variable that represents one aspect of the managed device. The collection of objects is referred to as a MIB. MIBs are specifications containing definitions of management information so that network systems can be remotely monitored, configured, and controlled [13]. The SNMP manager performs the monitoring function by retrieving the value of MIB objects. It can also cause an action to take place at an agent or can change the configuration settings at an agent by modifying the value of specific variables. There are two kinds of MIB. One is standard MIB to define the managed objects common to most systems defined by IETF. The other is private MIB to define the management information specific to the company. The standard MIB of SNMPv1 is MIB II defined in [14] and that of SNMPv2 is SNMPv2-MIB defined in [15].

C. PLC Network Management

Research on PLC network management has been carried out by the PLC chip vendors and project groups. Xeline in Korea is a main PLC chipset vendor as we mentioned previously. They defined their own PLC MIB and developed EMS software to manage the small PLC networks which are composed of master and slave modems. It has supported installation of PLC devices and to manage the configuration, fault, performance, and security of the devices. However, it is specific to their own solution package called XPAS-200B which is in-home PLC system using LV-PL (Low Voltage Power Line). The Korea Electrotechnology Research Institute (KERI) has deployed a pilot PLC network using MV-PL and LV-PL over a distance of approximately 5km in the Chunggae area, which is in a suburb of Euiwang city near Seoul, Korea [16]. They have developed PLC network management system to manage the pilot PLC network [11]. The ultimate goal of our study is to develop PLC NMS to manage a large-scale PLC network which is composed of various PLC devices from multiple vendors.

The Open PLC European Research Alliance (OPERA) [17] is a European, multi-organization R&D Project which aims to standardize PLC systems. OPERA has defined the private MIB in [18]. It is composed of 10 branches to provide PLC-related information based on the network layer. They have insisted that it has been a common PLC MIB, but currently it seems to be specialized to support DS2 PLC devices. And, IAP OMS-PLC of DCI [19] is a PLC network management system to manage DS2 PLC devices using this MIB. It has high flexibility and scalability to manage other networks as well as PLC network. But, it is also dependent to manage PLC network of DS2 PLC devices.

Systems we mentioned in this section have focused to manage the PLC system from the specific PLC vendor but have not been considering managing the general and heterogeneous PLC networks. In this paper, our proposed system focuses on the general PLC network and system management based on the definition of common PLC MIB.

III. DESIGN AND IMPLEMENTATION

A. Design

We designed our PLC NMS to support the PLC network as shown in Fig 3. This PLC network architecture is the reference model proposed by Xeline. It is not a general network topology but only an example of PLC network which we would like to manage by our proposed system. This PLC network is composed of master modem and slave modem as PLC devices. The master modem controls all slave and repeater units in a logical network and is the access point to the backbone network. The slave modem equivalent to the customer premise equipment (CPE) enables the end-user to access the Internet or home network from any electrical outlet in the household. We have been interested in the management of these PLC devices using SNMP. However, these PLC devices were not capable of supporting SNMP agent due to their low system resources. Thus, we considered one additional system as SNMP proxy agent to collect necessary information from the PLC devices. This system manages the faults, performance, and configuration of main NMS features.

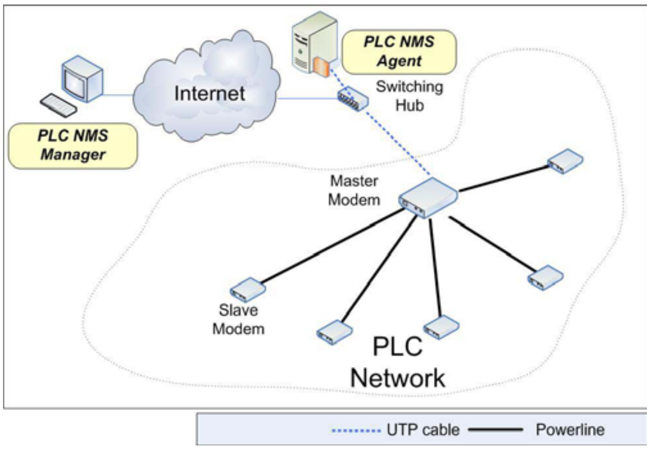

Fig 3. Target PLC network architecture

As we mentioned in the related work, SNMP manager and SNMP agent communicate based on the MIB which is a structured collection of managed objects. We have defined a common PLC MIB by analyzing existing PLC MIBs such as Xeline and OPERA PLC MIBs. Our MIB is composed of MIB II (RFC 1213) [14] and a private common PLC MIB as shown in Fig 4.

- System Node: General information of PLC device
- Interface Node: Interface information of PLC device
- Phy Node: Physical Layer information
- MAC Node: MAC Layer information
- Statistics Node: Statistics counter information
- Trap Node: Trap information of the PLC devices

The manager part of i-NetMSuite4PLC is composed of backend manager and frontend manager as shown in Fig 5. These two components can use the remote method invocation (RMI) as well as Socket over TCP for communication. The backend manager interacts with SNMP Proxy agent to manage the PLC devices and save the related information to the database. The frontend manager interacts with the administrator through web-based GUI to manage the PLC network.

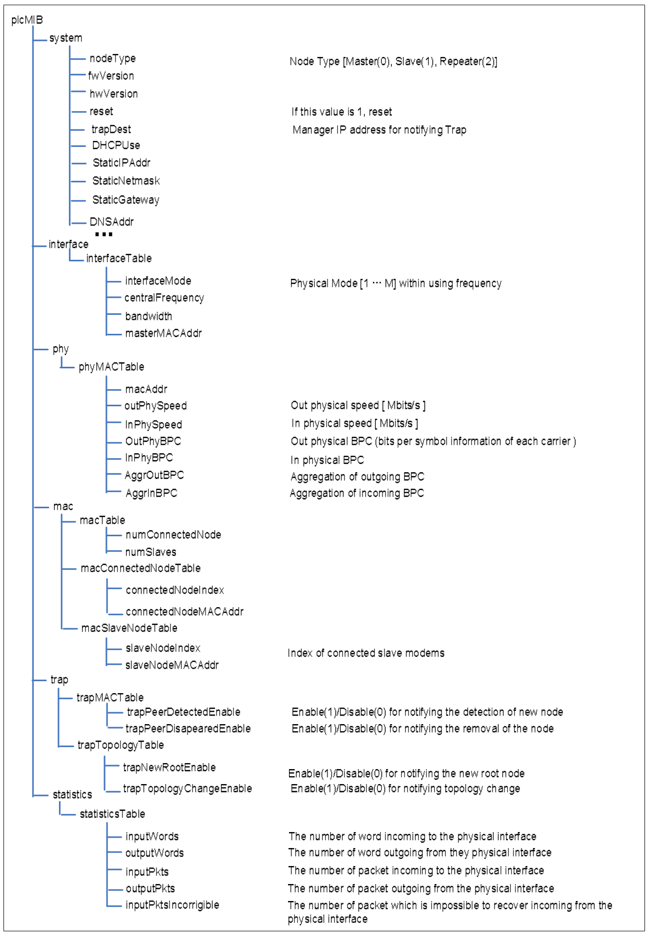

Fig 4. The definition of common PLC MIB

B. Implementation

We have implemented our i-NetMSuite4PLC on the development environment as shown in Table I. We have developed our manager part using Java [22] and web-based solution because it has a portable characteristic operated on any system environment. We have chosen Oracle database [26] to store management information because it is one of the best solutions for distributed system and large-data control system. AdventNet SNMP API [24] has been chosen to offer a comprehensive development toolkit for SNMP-based network management applications. It provides a set of powerful Java SNMP library to build real-time applications for monitoring and tracking network elements that are reliable, scalable, and OS independent.

We have implemented our common PLC MIB, defined previously, using the Abstract Syntax Notation One (ASN.1) [28]. The ASN.1 is used to define each individual object and also to define the entire MIB structure. And then, we have made a simple SNMP agent on the Linux using Net-Snmp library. Additionally, we have also applied our MIB to AdventNet SNMP Agent Simulator [20, 21] for testing scalability because it has been able to make many SNMP agents on a system.

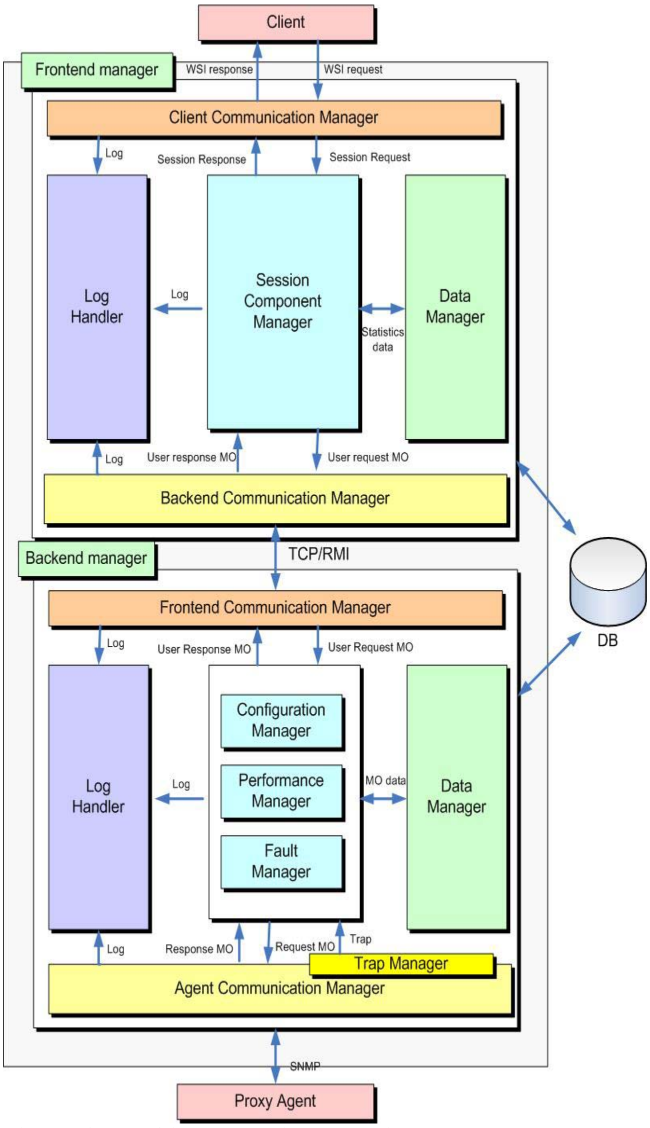

Fig 5. The Architecture of i-NetMSuite4PLC

Table I. Development Environment of i-NetMSuite4PLC

Manager	Language	Java 1.5.0_06
	OS	Windows XP Professional SP2
	IDE	Eclipse 3.1 [23]
	Library	AdventNet SNMP API
	Web server	Apache Tomcat 5.5 [25]
	Web client	JSP (Java Server Pages)
	Database	Oracle database 10g
Agent	OS	Linux Redhat 9.0
	Library	Net-SNMP 5.4
	Simulator	AdventNet SNMP Agent Simulator for Windows XP

IV. EXPERIMENT

A. Experiment Environment Setup

We have made the testbed of a PLC network as described in Table II [27]. We have installed a coupling unit to connect the power line to the backbone Internet on the power switch box in our research laboratory as illustrated in 1 and 2 of Fig 6. 3 shows the coupling unit and 4 shows PLC master modem and EMS Unit. And, we have tested our i-NetMSuite4PLC on this testbed. We have used a Xeline EMS unit as a proxy agent managing PLC devices. It supports the remote registration of PLC devices, management, monitoring, and firmware upgrade of the XPAS-200B PLC system. Actually, we have designed our common PLC MIB for the management and tested it on the simulation environment as we mentioned previously. When we tested the network management functions of our proposed system on the real PLC network environment, there was no solution to apply our common PLC MIB. So, we have tested our i-NetMSuite4PLC manager using the proxy agent of the Xeline EMS solution.

Table II. Testbed Environment

Test Area	108 m^2 Office	4 rooms
XPAS 200B solution	PLC Master Unit	1 unit
	PLC Slave Unit	5 units
	PLC Coupling Unit	1 unit
	PLC EMS Unit	1 unit
Chipset Characteristic	Payload data rate	Up to 24 Mbps
	Used band	2 ~ 23 MHz
	Modulation	PSK based DMT
	Duplex	Half duplexing
	Payload rate	Up to 24 Mbps
	UDP rate	Up to 16 Mbps
	TCP rate	UP to 10 Mbps
	No. of sub-carriers	256
	Bit loading	0/1/2/3 bits, adaptively
	Multiple access	CSMA/CA
	CMOS Technology	0.18 μm

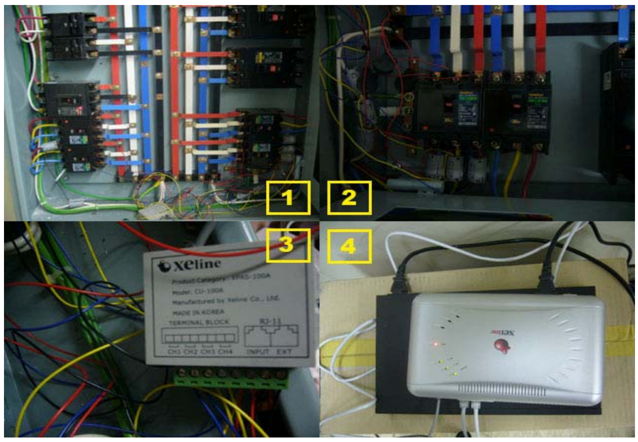

Fig 6. Installation of PLC devices

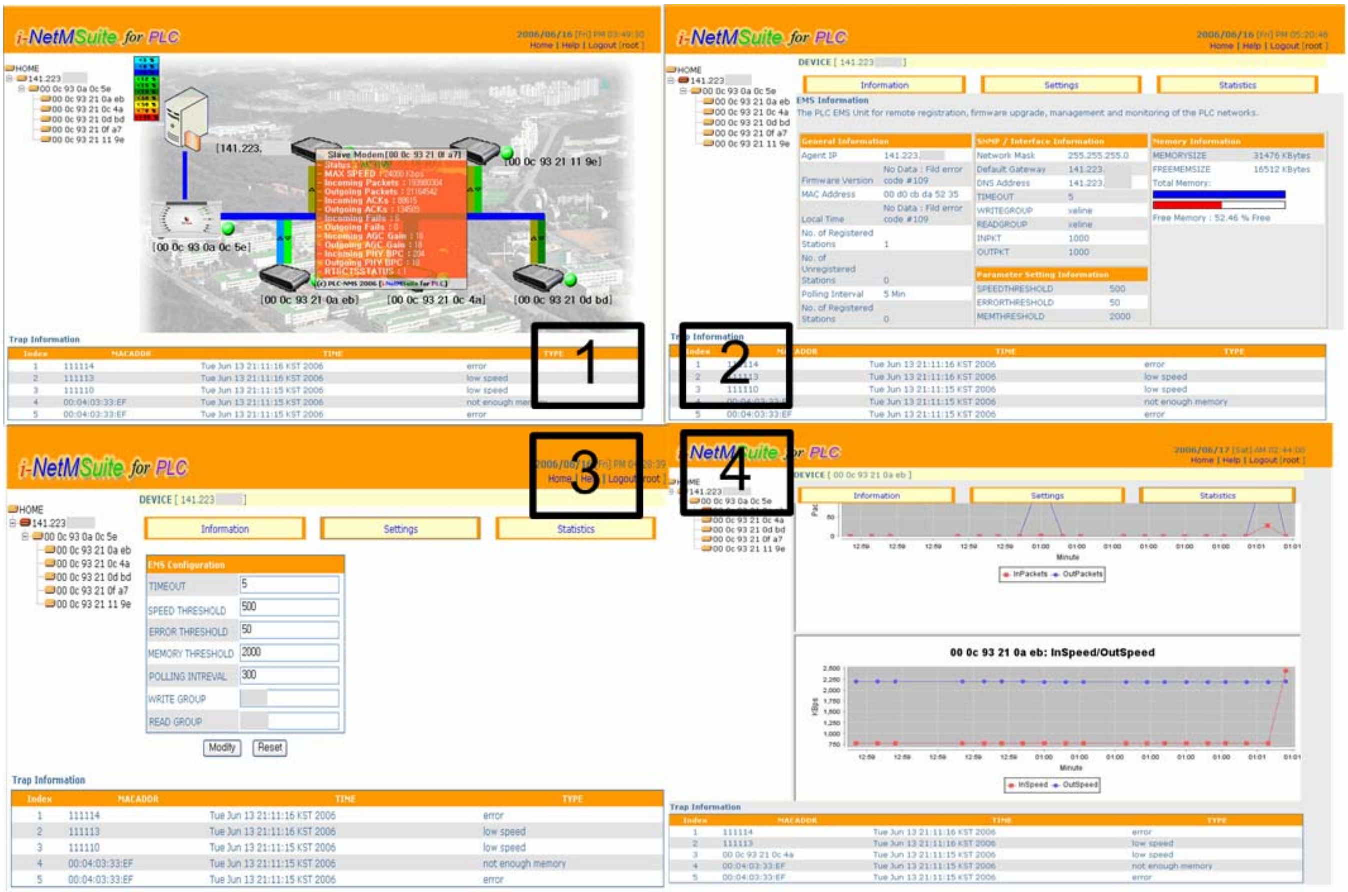

Fig 7. Test result of i-NetMSuite4PLC (1: Network topology map, 2: System information view, 3: System configuration setting view, 4: Performance view)

B. Experiment Result

We have tested the real PLC network using our i-NetMSuite4PLC. As shown in Fig 7, this system supports major functions to manage the PLC network. The authentication of the administrator and the users are supported on the login page. After the login, a network topology map shows the network status. It shows the general information of each PLC device such as PLC type, MAC address, and current status. It also shows the link utilization by the predefined color scheme dynamically. From the system information's view, the administrator is able to see all configuration information of each PLC device such as Agent IP address, MAC address, network setting information, and threshold values for detecting traps. From the system configuration setting's view, all modifiable parameters can be shown and the administrator is able to set some threshold values (e.g., timeout, speed threshold, error threshold, and memory threshold) and modify settings (e.g., polling interval and community information). From the performance's view, it shows the graphs of the statistics information based on the outgoing and incoming packets of the entire managed PLC network. We have tested 24 Mbps PLC modems and it shows 4.34 Mbps throughput on average on our testbed on measured by our PLC NMS. (Please note our backbone network is 100 Mbps). From trap's view located on the left bottom, the trap information such as trap occurred time, MAC address, and error type information can be shown ordered by the time.

V. Concluding Remarks

In this paper, we have briefly introduced the PLC network technology and motivated the need for PLC network management. We have also presented the design of common PLC MIB, and design and implementation of PLC NMS called i-NetMSuite4PLC for the heterogeneous PLC networks. We also installed PLC devices in order to test our proposed system on the testbed where we installed PLC devices for ourselves and presented the test result on the aspect of the network management. Our contribution of this study has been to provide the cornerstone of the PLC network management using the common PLC MIB based on the pure network management concept.

For future work, we plan to improve our PLC NMS to cover larger PLC networks and the common PLC MIB to support all kinds of PLC devices by analyzing various PLC MIBs. And then, we will have the performance test compared with other SNMP-based NMS for PLC. Further, we plan to refine and apply our common MIB to real PLC network devices. And, we have a plan to apply this PLC NMS to the real PLC network that will be deployed by Korea Electric Power Corporation (KEPCO) in 2007 in Korea.

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