An Integrated Network Management System for Multi-Vendor Power Line Communication Networks

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Abstract— **Power line communication (PLC) is an evolving communication network technology using pre-installed power lines, which provides the electricity to the household or the building, in order to provide services such as Internet access, Automatic Meter Reading (AMR) and home networking. As PLC networks and their applications grow with the advances in PLC technologies, we need to efficiently manage the resources of PLC networks. Currently, major PLC chipset and modem vendors are trying to provide network management capabilities in their devices by defining their own private management information base (MIB). However, it is insufficient to manage PLC networks comprised of multi-vendor PLC devices using a proprietary MIB. In this paper, we present our work on integrated network management of multi-vendor PLC networks. Particularly, we have focused on two aspects: 1) defining a common PLC MIB, the common management information for all types of PLC devices and 2) providing Integrated PLC Management System (IPMS). Our work can be used as a guideline for an international standardization for PLC network management.**

Keywords: Power line communcation (PLC), multi-vender PLC networks, common PLC MIB, Integrated PLC Management System (IPMS)

I. INTRODUCTION

POWER line communication (PLC) is a technology to enable data communication using pre-installed power lines which can provide the electricity to the household or the building [1, 2]. Recently, a lot of research is underway with the advances in PLC technologies such as commercializing 200 Mbps PLC devices; constructing the backbone network as well as access network and developing application services such as Automatic Meter Reading (AMR), home networking and triple play service [3, 4]. As PLC networks and their applications grow, we need to efficiently manage the resources of PLC networks.

PLC networks are currently composed of the following four vendors 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 chip sets [8]. Currently, PLC networks are independently constructed based on each chip set because PLC devices with different chip sets cannot communicate with each other. The PLC technology is under a standardization process for interoperability of all PLC devices by PLC chip vendors and project groups. The IEEE P1901 working group [9] is trying to create a “Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications”. It is in the selection process and the approved draft of a global standard is expected in 2008.

In contrast, the study on integrated management of PLC networks comprised of multi-vendor PLC devices is still in the early stage. Currently, some research and development on PLC network management has been carried out by the PLC chip vendors and project groups [12, 13]. Although they defined their own private PLC MIBs and developed their own element management systems (EMSs) to manage their PLC devices, these proprietary management information and systems are insufficient for supporting integrated management of multi-vendor PLC networks.

Due to the use of these proprietary management schemes, some problems exist. First, the cost of management system development is increased on account of considering features on all types of PLC devices. Second, owing to supporting all PLC MIBs that have duplicated management information, the management system has low efficiency of space and needs high maintenance of MIBs. Finally, the management system generates additional loads to find the object identifier (OID) to create the Simple Network Management Protocol (SNMP) message for the specific managed objects of each PLC device. To solve these problems, the standardization on the management of PLC networks is essential. As a first step of standardization, the management information for PLC networks should be standardized.

In this paper, we present the design and implementation of an integrated network management system to manage multi-vendor PLC networks. We first define a common PLC MIB, the common management information for all types of PLC devices, and then design and implement a Web-based Integrated PLC Management System (IPMS). We believe our work can be used as a guideline of an international standardization for the PLC network management.

The organization of this paper is as follows. In Section II, we explain a structure of PLC network and the trend of PLC network management technology. In Section III, we present the design of a common PLC MIB. In Section IV, the requirements and design for IPMS are presented. In Section V, we describe the implementation of our proposed IPMS. In

Section 6, we summarize our work and discuss possible future work.

II. RELATED WORK

In this section, we briefly present an overview of a PLC network structure and the trend of PLC network management technology.

A. Structure of PLC Network

PLC can be divided into Medium Voltage (MV) PLC and Low Voltage (LV) PLC as shown in Figure 1 [10]. The MV PLC uses 22.9 kV power line between the substation and the transformer. The LV PLC uses 110V or 220V power line between the transformer and the household. The PLC network is composed of various PLC devices such as master modem, slave modem, repeater modem, and MV/LV gateway [11]. A master modem is a device used to connect the backbone network (such as fiber network, xDSL or cable network) to the PLC network. A repeater modem is a device used to amplify the signal between various PLC devices. A slave modem is a device used to transfer the signal between PLC network and home devices such as desktop PCs. A MV/LV gateway intermediates between MV PLC and LV PLC. PLC Operating Center manages the PLC networks through the Internet.

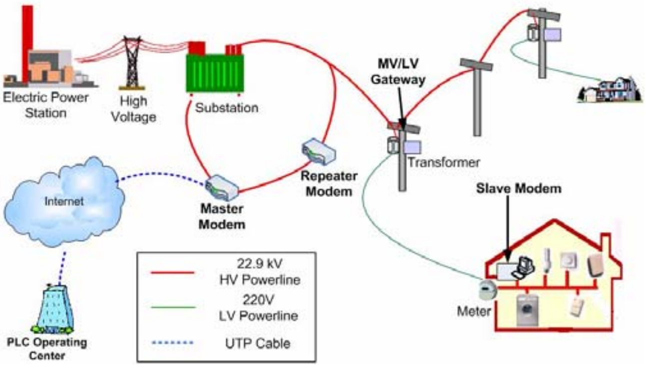

Figure 1. Structure of PLC Network

B. Trend of PLC Network Management Technology

Research on PLC network management has been carried out by the PLC chip vendors and project groups. Some of them have constructed an SNMP-based network management framework, while others are still on trying. Xeline and Open PLC European Research Alliance (OPERA) have defined and used their private MIBs, whereas Intellon and Panosonic are in progress.

In this Section, we compare and analyze the features and the common information of existing OPERA MIB [12] and Xeline MIB [13] to examine the information for the PLC network management.

Xeline in Korea is a leading PLC company, which makes PLC devices such as PLC modems as well as PLC chipsets. It has defined a private PLC MIB, and developed a network management system. The Xeline MIB is composed of nine groups categorized by their system model name [13, 15]. Since most parts of Xeline MIB are defined to manage its own PLC device (e.g., XPAS-200B), it includes more private management information specialized to its devices. Further, because the Xeline modems do not embed an SNMP agent, a new device (EU-200B) playing the role of a proxy-agent between the manager and the modems is added. The proxy-agent translates the SNMP messages, received from the manager into the proprietary messages, supported by the modems.

The OPERA [14] is a European, multi-organization R&D Project which aims to standardize PLC systems. The OPERA has defined a private MIB for managing its PLC devices. The MIB is composed of ten groups to provide PLC-related information based on the network layer [12, 15]. It is specialized to support DS2 chip set based PLC devices. Because management structure of OPERA assumes that all devices have their own IP address and embed SNMP agents, it is difficult to manage PLC networks using a proxy-agent with OPERA MIB.

OPERA MIB and Xeline MIB have different structure and information, because they have different management structure and merely manage their own PLC devices. However, in terms of network management functionality, they have much common information: basic, configuration, fault, performance information, etc.

The common information is as follows:

1. basic information: MACAddr, NodeType, Status and so on
2. configuration information: MACAddr of parent node, number of connected node, AGCGain, ToneMap and so on
3. performance information: in/out speed, in/out number of octets, in/out BPS (Bits per Symbol) and so on
4. fault information : trap information in case of changing device status and network topology

Additionally, there are functional common information such as remote-upgrade information and security information

III. DESIGN OF COMMON PLC MIB

In this section, we present the design of a common PLC MIB based on the comparison and analysis of existing PLC MIBs [15]. Figure 2 shows multi-vendor PLC networks, which are comprised of independent cells based on various vendors.

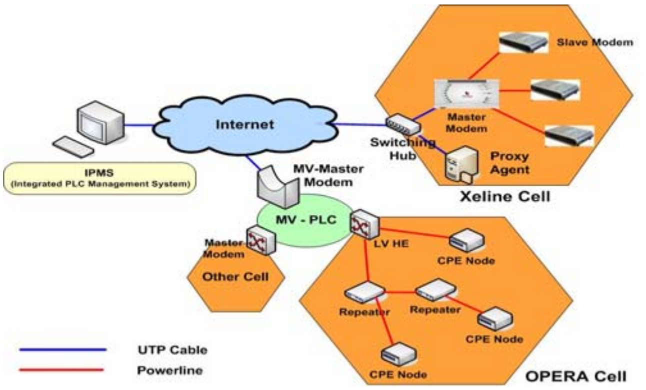

Figure 2. Multi-Vendor PLC Network

Managing multi-vendor PLC networks with existing private PLC MIBs causes some problems. First, the cost of developing the management system increases on account of considering the features of all types of PLC devices. Second, Due to supporting all PLC MIBs, which have duplicated common management information, the management system has low efficiency of space and needs high maintenance of MIBs. Finally, the management system has additional loads to find OID for creating an SNMP message. To solve these problems, common management information should be defined as a common PLC MIB, and only the information specific to a vendor should be defined as a private MIB.

The common PLC MIB is essential management information for all types of PLC devices. We have designed it based on the comparison and analysis of the existing PLC MIBs in Section III.B. It needs to support a proxy-agent management structure (Xeline) as well as an SNMP agent management structure (OPERA, DS2). For this, we defines system group as MIB tables and references the system and interface groups of MIB-II (RFC 1213) [16] in order to support system basic information of the managed devices that do not have SNMP agents. Thus, the proxy-agent can support basic system and interface information of its own managing devices. Figure 3 shows our proposed common PLC MIB. It is composed of four groups.

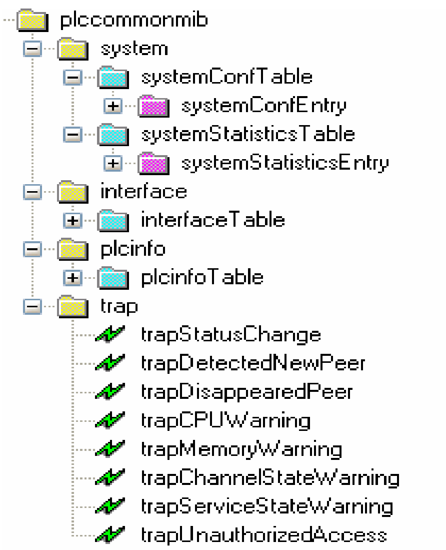

Figure 3. Structure of Common PLC MIB

The **system** group includes general system information such as MAC Address, NodeType, Status and so on. It is defined as a MIB table to contain information for many devices for supporting a proxy-agent management structure. It is classified into two tables, systemConfTable that contains static system configuration information and systemStatisticsTable that contains dynamic and statistical system monitoring information, to improve efficiency of polling.

The **interface** group includes interface information such as interface status, in/out octets and so on. It contains main interface information of MIB-II to support a proxy-agent management structure.

The **plcInfo** group includes information specific to PLC technology such as in/out BPS (Bits per Symbol), Tonemap that shows overall channel state, and so on. plcOutBPS and plcInBPS are important information to decide whether a fault occurs or not, since they are used to estimate the physical interface speed.

The **trap** group includes information of trap which occurs in the case that the network topology changes or a problem arises on the system.

In terms of management functionalities, a common PLC MIB is essential management information for all types of PLC devices. Therefore, managing PLC networks with a common PLC MIB has a good effect of higher efficiency of space and lower maintenance of MIBs than managing PLC networks with multiple private MIBs, because duplicate management information is removed. Moreover, the cost of management system development will be decreased.

The common PLC MIB does not include information specific to each vendor such as security management information or remote upgrade information. The information specific to each vendor is defined as a private MIB.

IV. Design of IPMS

In this section, we discuss requirements that should be considered for the development of Integrated PLC Management System (IPMS) and present our IPMS architecture in accordance with the requirements.

A. Requirements

The basic role of IPMS is monitoring and control of multi-vendor PLC networks with the common PLC MIB. However, it should also manage the existing PLC devices that do not support the common PLC MIB.

The IPMS requires the following management functionalities:

1. Configuration management
   - ✓ *add and delete PLC device*
   - ✓ *monitor and control PLC device configuration and connectivity information*
2. Fault management
   - ✓ *notify PLC device problems*
   - ✓ *report fault records*
3. Performance management
   - ✓ *monitor, analyze and report performance data*
4. Subscriber management
   - ✓ *add, delete and modify subscriber information*

The non-functional requirements of IPMS are as follows. First, the IPMS should manage existing PLC devices that only support their private PLC MIBs and do not support the common PLC MIB. Second, it should be scalable to support the management of thousands of PLC devices. Third, all modules should be functionally independent in order to minimize their effects on other modules. Finally, it should support multi-platform and provide a standard interface to support interoperability between the management tiers.

B. *Architecture*

We have designed our IPMS based on a 3–tier architecture. It consists of three elements: the Front End (F/E) Server, the Middleware Server and the Gateway Server. Figure 4 shows the overall architecture of our IPMS.

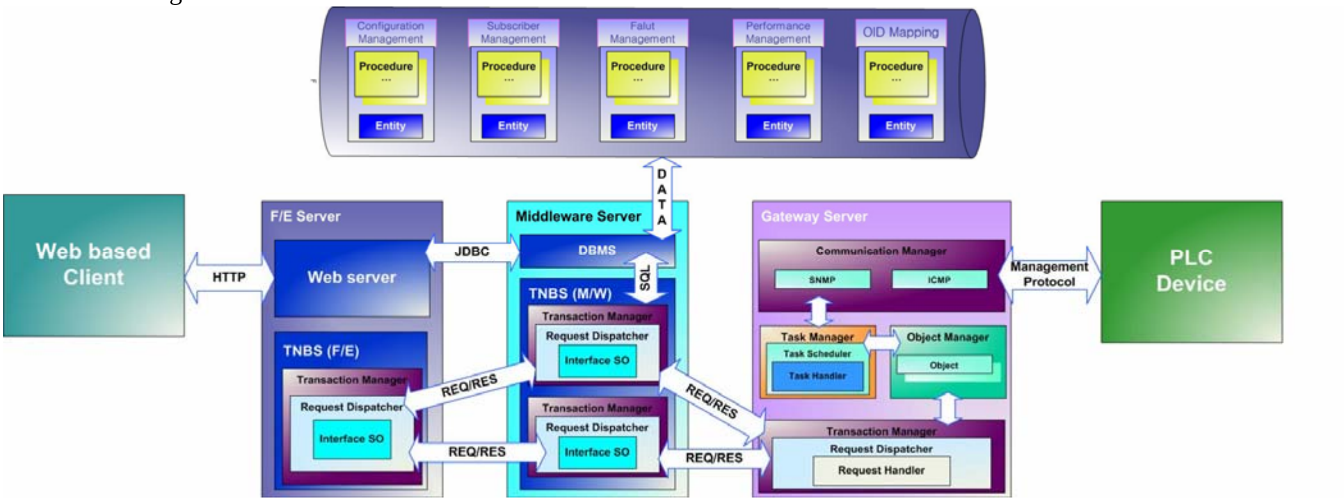

Figure 4. Architecture of IPMS

The F/E Server is in charge of communication with Web-based Client as a presentation tier. The Middleware Server intermediates between the F/E Server and the Gateway Server by managing DB as a Data Tier. The Gateway Server substantially manages PLC networks by communicating with PLC devices as a Business Tier. DB contains business logic and data structure for configuration management, performance management, fault management, and subscriber management. DB also includes OID mapping information to manage PLC devices that do not support the common MIB. To manage PLC devices that do not support the common MIB, the IPMS can acquire OID in the corresponding vendor private MIB by using OID mapping information in DB.

The Transaction based Service (TNBS) is composed of the Transaction Manager and the Interface Shared Object (ISO). The Transaction Manager only manages transactions on the communication with other tiers, while ISO retrieves business logic data from DB and processes it by plugging-in to the Transaction Manager when needed. Due to a flexible structure of the plugging-in ISO, IPMS can have the scalability to sustain concentrated load to the Middleware Server.

The Transaction Manager processes management requests from a user through the Request Dispatcher, and forwards a notification and response from the devices. The Task Manager schedules and processes management tasks which execute in the Gateway Server. The Object Manager supports data modeling which is needed to implement business logic with various data structures in DB. The Communication Manager is in charge of communication with devices with various protocols.

Client and F/E Server communicate using the HTTP protocol. The F/E Server, Middleware Server and Gateway Server communicate using the communication API of Transaction Manager.

V. Implementation of IPMS

We have implemented an IPMS based on the IPMS design presented in Section IV.B. We have developed the IPMS using JAVA (jdk 1.5.0_06), Eclipse, Apache Tomcat 5.5 and AdventNet SNMP APIs [17] on Window XP SP2. We have chosen Oracle 10g as a database.

The IPMS supports all the management functionalities mentioned in the Section IV. Figure 5 shows a main user interface.

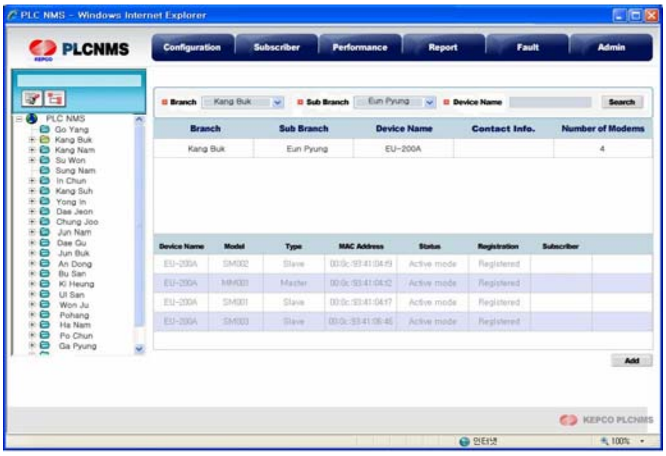

Figure 5. User Interface of IPMS

Since our IPMS provides a Web-based management user interface, the user can easily access it with Web browser. The left part of the Figure 5 is the tree view panel, which shows the connectivity hierarchy of PLC devices. If the user chooses some regions or devices in the center part or double-clicks some icons in the tree view panel, then the device list of selected region or management information of selected device appears in the right part of the Figure 5. The right part of Figure 5 shows following information: MAC Address, Operating Status, registering Status, and User basic information.

Figure 6 shows the performance data report. If the user selects a device, the performance data type and the duration, then the statistics of the performance data for the duration appears as graphs in the center part.

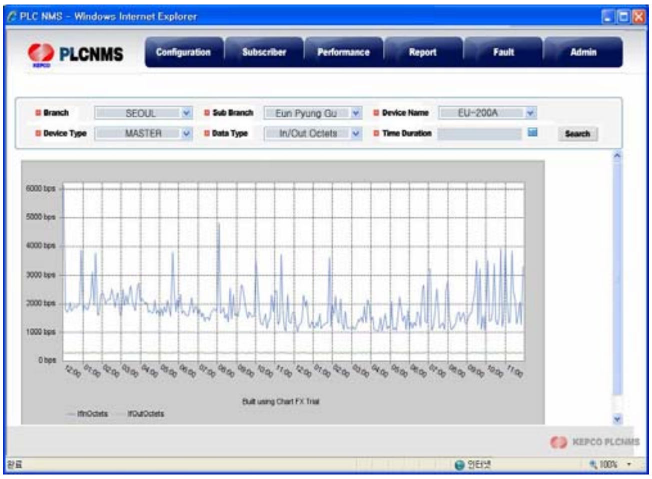

Figure 6. Performance Report of IPMS

VI. CONCLUSION AND FUTURE WORK

PLC technology using the existing power line arouses interest in the entire world due to its cost efficiency and accessibility. As PLC networks and their applications grow, the needs for a general PLC network management framework are increased. However, research on integrated management for multi-vendor PLC networks is insufficient. In this paper, we proposed an integrated network management system to efficiently manage multi-vendor PLC networks. We defined a common PLC MIB, the common management information for all types of PLC devices, then designed and implemented a Web-based Integrated PLC Management System (IPMS).

For future work, we will validate a common PLC MIB and our proposed system after building a large-scale multi-vendor PLC network test-bed using existing PLC devices and new PLC devices that support a common PLC MIB.

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