Definition of Common PLC MIB and Design of MIB Mapper for Multi-vendor PLC Network Management

Chang-Keun Park, Joon-Myung Kang,
Mi-Jung Choi, and James Won-Ki Hong
Dept. of Computer Science and Engineering, POSTECH,
Pohang, KOREA
{pck1982, eliot, mjchoi, jwkhong}@postech.ac.kr

Yong-hun Lim, Seongho Ju and Moon-suk Choi
Korea Electric Power Research Institute (KEPRI), Daejeon,
KOREA
{adsac, shju1052, 05100097}@kepco.co.kr

***Abstract*—Power Line Communication (PLC) is an evolving technology which uses the existing power lines for data transmission. Like any other communication networks, PLC networks need to be managed for efficient use of resources and secure operations. Major PLC chipset and modem vendors are trying to provide network management solutions using SNMP by defining their own management information, but it is not sufficient to manage a multi-vendor PLC network comprised of PLC devices from heterogeneous vendors. In this paper, we propose an integrated management method of multi-vendor PLC network. We define a common PLC MIB by analyzing existing proprietary PLC MIBs and design a common PLC MIB Mapper for managing existing PLC devices without the support of common PLC MIB. Our work can be a reference model for integrated PLC network management to PLC vendors, and contribute an international standardization for PLC network management.**

Keywords: PLC (Power line communcation), , multi-vendor PLC networks, common PLC MIB (Management Information Base), MIB Mapper

I. Introduction

POWER line communication (PLC) is a technology to enable data communication using pre-installed power lines which provide the electricity to the household or the building [1, 2]. Recently, PLC has been used for AMR (Automatic Meter Reading), home networking, and high-speed Internet service. Like any other communication networks, PLC networks need to be monitored and controlled for efficient use of resources and secure operations. Currently, Simple Network Management Protocol (SNMP) [3, 4] standardized by the Internet Engineering Task Force (IETF) [5] is the most widely used protocol for managing IP-based communication networks including PLC networks [6, 7].

As shown in Table I, PLC networks are currently composed of the following four types of PLC devices using: 1) DS2 chip sets [8], 2) Intellon chip sets [9], 3) Xeline chip sets [10], and 4) Panasonic chip sets [11]. All vendors have implemented or planned to implement the SNMP based PLC network management solution. Until now, DS2, Xeline and Intellon have defined private PLC MIBs and implemented SNMP agents in their own devices. Panasonic is currently working towards defining PLC MIBs based on their PLC chip sets. However, typical PLC networks are composed of PLC devices from multiple vendors, possibly developed using different chip sets. In order to provide an integrated management of these heterogeneous devices using the SNMP mechanism, it is the most essential to define a common PLC MIB.

Table I. Comparison of existing PLC network management technology

	Management Protocol	Management Information	Management Structure
Xeline	SNMP	Xeline Private MIB	SNMP Proxy Agent
DS2 (OPERA)	SNMP	OPERA Private MIB	SNMP Agent
Intellon (Homeplug)	SNMP	HomePlug Private MIB	SNMP Proxy Agent
Panasonic	SNMP	In Progress	In Progress

The study on an integrated management of multi-vendor PLC networks is still in the early stage. Currently, some research and development on PLC network management has been independently carried out by the PLC chip vendors and NMS solution vendors. Although they have defined their own private PLC MIBs and developed their own element management systems (EMSs) to manage their own PLC devices, problems exist in supporting the integrated management of multi-vendor PLC networks with proprietary management information and systems.

The first problem is that the management system must support all private MIBs that include duplicated management information for managing multi-vendor PLC devices. Therefore, the management system has low efficiency of space and needs high maintenance of MIBs. Second, it is difficult to integratedly manage PLC networks that have different management information structures. Finally, on account of considering features of all types of PLC devices, the management system cannot provide an integrated management view and the development cost of management system also increases.

To solve these problems, an effort for defining common management information is necessary. It is desirable that common management information for all types of PLC devices is defined by a standard PLC MIB and other management information specific to each vendor PLC device is defined by a private MIB.

In this paper, we propose an integrated management method for multi-vendor PLC networks. We define a common PLC

MIB by analyzing existing PLC MIBs and design a common PLC MIB Mapper for managing legacy PLC devices that do not support the common PLC MIB.

The remainder of this paper is organized as follows. Section II presents a comparative analysis of existing PLC network management approaches. Section III presents the design of a common PLC MIB, and Section VI presents the design of a common PLC MIB Mapper. Finally, conclusions and future work are discussed in Section V.

II. Analysis of Existing PLC Network Management Approaches

In this section, we present a comparative analysis of existing PLC network management approaches. Three PLC vendors such as OPERA (DS2) [12], Xeline and Homeplug (Intellon) [13] provide SNMP-based management. Parasonic [11] is now starting to consider SNMP-based management. We perform a comparative study in terms of management information and structures. Through this study, we extract essential management information as the basis for defining a common PLC MIB.

A. PLC Management Approaches

Fig. 1 shows the overall architecture of multi-vendor PLC network composed of three groups such as OPERA (DS2), Xeline and Homeplug (Intellon). It also shows the network and management structure of three groups.

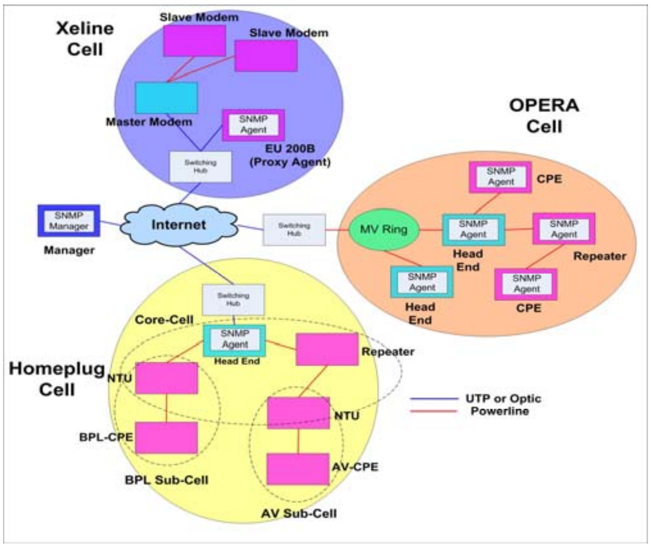

Fig. 1. Overall Architecture of Multi-vendor PLC network

Xeline in Korea is a leading PLC company, which manufactures PLC devices such as PLC chipsets as well as PLC modems. It has defined a private PLC MIB for managing its own devices, and developed a network management system. A Xeline network is composed of master modem, slave modem, and SNMP proxy agent as shown in Fig. 1. The slave modem can act as a repeater modem in the case that the distance between the master modem and the slave modem is long. The management structure of Xeline is named as the SNMP Proxy Agent structure. The proxy agent called EU 200B manages the Xeline network because the PLC modems do not embed an SNMP agent. It translates the SNMP messages received from the manager into the proprietary messages supported by the modems.

OPERA led by DS2 is a project to standardize PLC network in Europe that started in 2004. Its goal is to develop a PLC technology that can become an alternative for a broadband access integrated network suitable for being commercialized and to deploy it to all areas of Europe [12]. OPERA network is composed of one or more PLC Cells. The PLC Cell is divided into Medium Voltage (MV) Cell and Low Voltage (LV) Cell. The MV Cell forms a ring topology, which is composed of one or more MV Node. The LV Cell is a basic management unit consisted of a Head End (HE), several Repeaters (REP), and Customer Premises Equipment (CPE). HE is a central node to control PLC Cell and acts as a master of all nodes connected to it. REP connected to HE or other REP amplifies the signal. CPE is a PLC modem installed at the customer’s home. All these nodes are equipped with an SNMP agent. Thus, we named the management structure of OPERA as SNMP Agent structure. In this architecture, an SNMP manager can manage all PLC devices directly via SNMP.

Homeplug led by Intellon is an industry Alliance comprised of industry leaders. Its goal is to standardize PLC technology for interoperability of PLC devices. Homeplug network is composed of one or more PLC Cells. The cell is divided into Core Cell, BPL Sub-Cell, and AV Sub-Cell. A Core Cell consists of a group of devices that share the same network encryption key. It includes the Head End (HE), Repeaters (REP) and Network Termination Units (NTU). The AV Sub-Cell is an extension Cell that is based on AV protocol and provides for the connection of multiple AV-CPEs to the Core Cell via active NTU. The BPL Sub-Cell is an extension Cell that is based on BPL protocol and provides for the connection of multiple BPL-CPEs to the Core Cell via active NTU. The management structure of Homeplug follows the SNMP Proxy agent structure as Xeline. HE includes an SNMP Proxy agent for managing PLC devices in the cell. The SNMP Proxy agent translates SNMP requests into MMEs (Management Message Entry Data) which are sent from the HE to other PLC devices in the cell.

B. Existing PLC MIBs

Xeline PLC MIB [14] is a definition for managing the PLC modems of XPAS-200B system for low voltage power line network. Fig. 2 shows the structure of Xeline PLC MIB. The Xeline MIB is composed of nine groups categorized by their system model name. Currently, the management information for XPAS-200B is defined in the *xelineXPAS200BModule* group and the management information for EU 200B is defined in the *xelineEU200BModule* group. Since most parts of Xeline MIB are defined to manage its own PLC devices (e.g. XPAS-200B), it includes more private management information specialized to its devices.

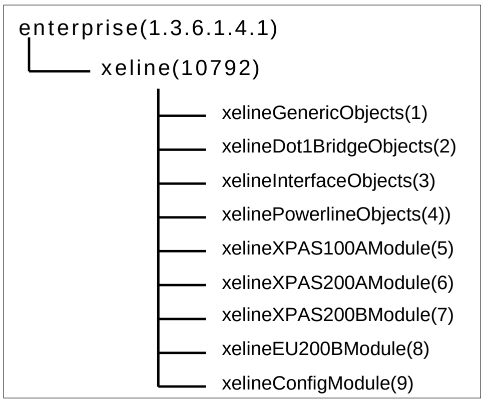

Fig. 2. Structure of Xeline PLC MIB

Fig. 3 shows the structure of OPERA PLC MIB, which is composed of ten groups to provide PLC-related information based on the network layer [15]. It is specialized to support PLC devices using the DS2 chipset. Since the management structure of OPERA assumes that all devices have their own IP address and embed SNMP agents, it is difficult to manage PLC networks based on the SNMP Proxy agent structure like Xeline and Homeplug with the OPERA MIB.

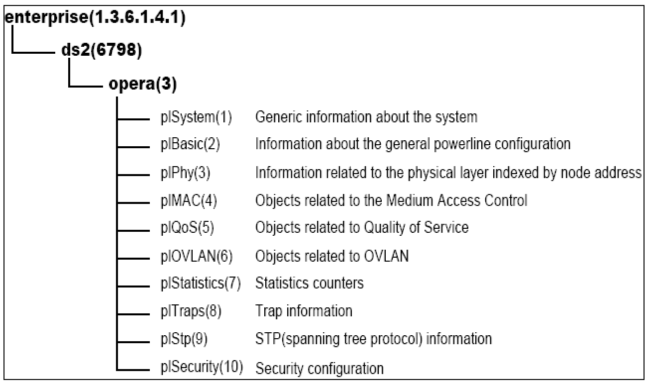

Fig. 3. Structure of OPERA PLC MIB

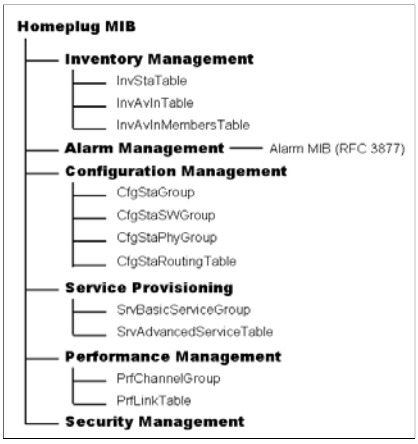

Fig. 4. Structure of Homeplug PLC MIB

Fig. 4 shows the structure of Homeplug PLC MIB, which is composed of six groups categorized by network management functionality [16]. The *Inventory Management* group contains information of PLC network topology and discovery. The *Alarm Management* group contains alarm information, which references Alarm MIB (RFC 3877). The *Configuration Management* group contains managed parameters for amplitude maps, routing, repeating, and firmware upgrades. The *Service Provisioning* group contains traffic shaping parameters. The *Performance Management* group contains statistics information of the channel, link, and IP layer. The *Security Management* group contains security information such as key value to join the cell.

C. Comparative Analysis of PLC MIBs

Table II shows analysis results of existing PLC MIBs based on management structure and management functionalities.

Table II. Comparative analysis of existing PLC MIBs

	OPERA MIB	Homeplug MIB	Xeline MIB
Management Structure	SNMP Agent (All PLC devices have SNMP agent)	SNMP Proxy Agent (Head End device has SNMP Agent)	SNMP Proxy Agent (All PLC devices do not have SNMP agent)
Configuration Management	✓ plSystemGroup ✓ plBasicGroup ✓ plMAC Group	✓ Inventory Group ✓ Configuration Group	✓ DeviceInfoTable ✓ EURegistration (MACArray) ✓ EUManagementTable (ManagementMAC)
Fault Management	✓ plTrapsGroup	✓ Alarm Group	✓ XPAS200BTrapGroup ✓ EU200BTrapGroup
Performance Management	✓ plStaticsTable ✓ plPhyGroup	✓ Performance Group	✓ NodeInfoTable ✓ InterfaceTable
Security Management	✓ plSecurity Group	✓ Security Group ✓ SNMP v3 is used	✓ DeviceInfoTable (GroupID)
System Upgrade	✓ plSystemTable (plSysUpgradeStatus, plSysUpdate)	✓ Configuration Group (CfgStaSWGroup)	✓ RemoteUpgradeTable

The existing PLC MIBs have different management structure and information which can merely manage their own PLC devices. However, from the perspective 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 the 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 in Section II. To provide an integrated management view, the SNMP manager should manage multi-vendor PLC network shown in Fig. 1. However, it has some problems mentioned in Section I to manage multi-vendor PLC network using existing PLC network management frameworks. To solve these problems, standardization of management information is essential.

A common PLC MIB is composed of the common management information for all types of PLC devices. Furthermore, it should consider the following two network architectures as the target network: the network where each device embeds its own SNMP agent like OPERA (SNMP Agent Structure), and the network where each device does not have its own SNMP agent and the proxy agent provides the management information like Xeline and Homeplug (SNMP Proxy Agent Structure).

We have designed a common PLC MIB composed of four groups: 1) system, 2) interface, 3) plcinfo, and 4) trap. This information includes configuration, performance, and fault management for integrated PLC network management. If vendor-specific management information is additionally necessary, then it should be defined as a private MIB. Each group includes a MAC address as the index of table because devices managed by the proxy agent do not have an IP address. Furthermore, the MAC address is sufficient in identifying the system because the structure of target network is a tree topology in a cell.

Fig. 5 shows the structure of our proposed common PLC MIB.

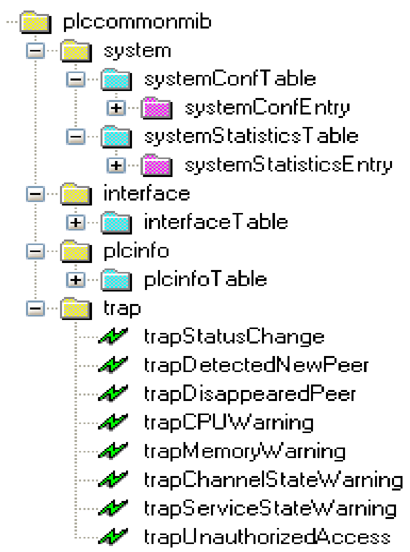

Fig. 5. Structure of Common PLC MIB

The ***system*** group includes general system information such as MAC address, node type, status, and so on. It is defined as a MIB table to contain information for many devices to support an SNMP Proxy agent structure. It is classified into two tables to improve efficiency of polling: 1) *systemConfTable* that contains static system configuration information and 2) *systemStatisticsTable* that contains dynamic and statistical system monitoring information.

The ***interface*** group includes interface information such as interface status, in/out octets, and so on. It references interface group information of MIB-II [17] and forms a table to support the SNMP Proxy Agent management structure.

The ***plcInfo*** group includes information specific to PLC technology such as in/out BPS (Bits per Symbol), tone map 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 since duplicate management information is removed. Moreover, the management system can provide an integrated management view and the cost of management system development can decrease. The common PLC MIB does not include management 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 Common PLC MIB Mappper

In this section, we explain the requirements and architecture of a common PLC MIB Mapper for managing existing PLC devices that do not support the common PLC MIB.

A. Requirements

A common PLC MIB Mapper is a gateway device to perform OID mapping between the SNMP manager supporting a common PLC MIB and SNMP agent which does not support it. Fig. 6 shows the operation of common PLC MIB Mapper. Owing to the common PLC MIB Mapper, the SNMP manager can provide an integrated management view including the legacy PLC devices with SNMP agents which do not support the common PLC MIB.

Our common PLC MIB Mapper requires the following functionalities. First, it should perform OID mapping on the same management information between the common PLC MIB and existing PLC MIBs. Second, it should parse, generate, and translate SNMP messages between the SNMP manager supporting the common PLC MIB and the legacy SNMP agent which does not support it. Third, it needs to guarantee the same management performance to existing PLC devices compared with the PLC devices supporting the common PLC MIB. Finally, it should be scalable to support the management of thousands of PLC devices.

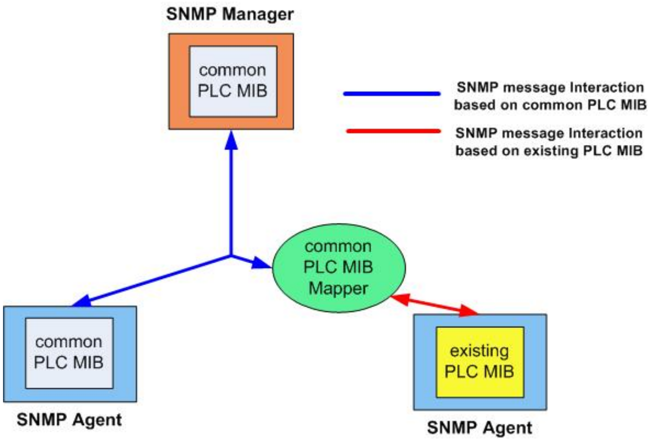

Fig. 6. Operation of common PLC MIB Mapper

The common PLC MIB Mapper can be physically located in three places. First, it can be loaded in the SNMP manager system. Second, it can be located in the PLC device together with SNMP agent. Finally, it can be independently placed between the manager system and the PLC device as a gateway device shown in Fig. 7.

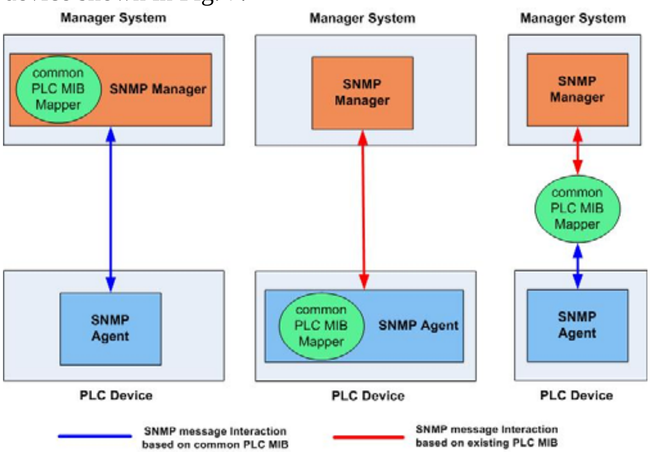

Fig. 7 Possible locations of common PLC MIB Mapper

We have previously studied the first case, in which the manager system can perform the OID mapping function with OID mapping information in database. In this case, the mapping operation is performed in the SNMP manager, so it does not need an additional translation between the SNMP messages based on common PLC MIB and the existing PLC MIB. However, the processing overhead and development cost of the manager system increases because it should store OID mapping information on all existing PLC MIBs and perform the OID mapping operation.

In the second case, the SNMP manager can communicate with the SNMP agent without performing an additional translation because the SNMP agent executes the OID mapping operation internally and the complexity of OID mapping operation is moved to the device. The SNMP agent needs to merely support own existing MIB. However, the processing overhead and resource usage of PLC device are increased because the OID mapping operation as well as data transmission operation need to be performed.

In the last case, although the burden of PLC device and manager system does not increase, the SNMP manager should communicate with the SNMP agent through the Mapper with the additional translation, and the independent gateway system is also necessary. We have chosen the last case because it can reduce the burden of manger system and PLC device and support management structure based on the common PLC MIB without changing the existing PLC devices.

B. Architecture

Fig. 8 shows the architecture of our proposed PLC MIB Mapper.

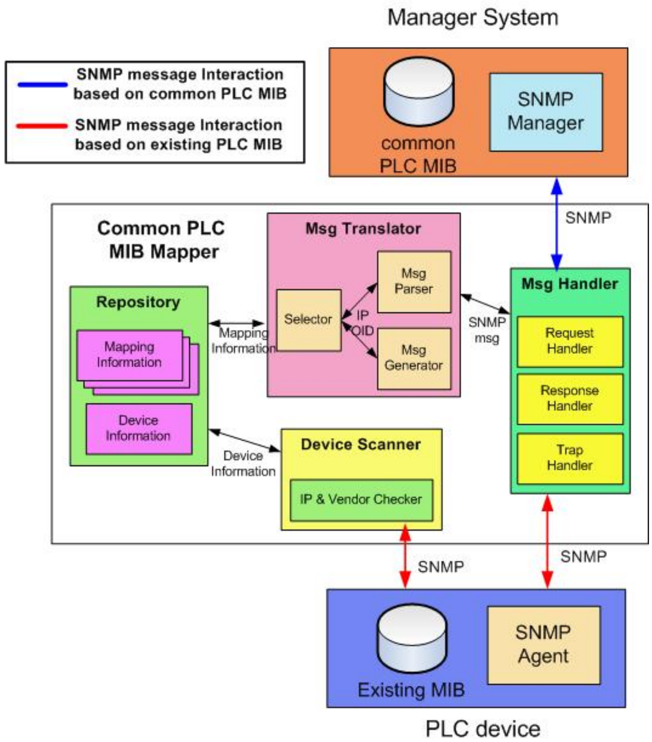

Fig. 8. Architecture of common PLC MIB Mapper

The common PLC Mapper consists of four elements: *Msg Handler*, *Msg Translator*, *Device Scanner* and *Repository*. The *Msg Handler* classifies the SNMP messages received from the manager system or the PLC device according to message types: request, response, and trap. It delivers them to the *Msg Translator*. The *Request Handler* handles the SNMP request messages from the manager system. The *Response Handler* handles the SNMP response messages from PLC devices. The *Trap Hander* handles the SNMP trap messages from PLC devices. The *Msg Translator* performs translation between the SNMP messages based on common PLC MIB and existing PLC MIB. The *Msg Parser* extracts IP and OID information from the SNMP message, and delivers them to the *Selector*. The *Selector* decides the correspondent OID by using IP and OID information from the *Msg Parser* and mapping information in the *Repository*, and delivers it to the *Msg*

Generator. The *Msg Generator* generates the SNMP message by using OID information from the *Selector*, and delivers it to the *Msg Handler*. The *Repository* contains OID mapping information between the common PLC MIB and existing PLC MIBs as well as managed device information. The *Device Scanner* manages the list of managed device and each device's information. The *IP & Vendor Checker* checks vendor information of managed PLC devices.

In case of SNMP request message from the manager system, process sequences of the PLC MIB Mapper are as follows. First, the *Msg Handler* receives an SNMP request message based on the common PLC MIB, and delivers it to the *Msg Translator*. Next, the *Msg Translator* translates the SNMP message into the correspondent SNMP message based on the existing PLC MIB by using mapping information in the *Repository*, and delivers it to the *Msg Handler*. Then, the *Msg Handler* sends it to PLC devices. In case of the response message based on the existing MIB from PLC devices, the process flows are almost similar to the above.

V. CONCLUDING REMARKS

In this paper, we proposed an integrated management method of multi-vendor PLC networks. We presented the definition of common PLC MIB for standardization of PLC management information and the design of PLC MIB Mapper for managing existing PLC devices that do not support the common PLC MIB. Our work can be a guideline for the integrated PLC network management to PLC vendors, and contribute an international standardization of management information for PLC network management.

Recently, we have developed a PLC device with an SNMP agent supporting the common PLC MIB. For future work, we plan to validate our common PLC MIB and common PLC MIB Mapper in the PLC network service trial testbed that KEPRI is currently constructing..

ACKNOWLEDGMENTS

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REFERENCES

[1] Niovi Pavlidou, A.J. Han Vinck, Javad Yazdani, "Power Line Communications: State of the Art and Future Trends," IEEE Communications Magazine, April 2003, pg 34-40.

[2] A. Majumder and J. Caffery, "Power line communications," IEEE Potentials, Vol. 23, Issue 4, October/November 2004, pp. 4-8.

[3] W. Stallings, "SNMP, SNMPv2, SNMPv3 and RMON 1 and 2," 3rd edition, Addison-Wesley, Reading, MA, USA, 1999.

[4] A Simple Network Management Protocol (SNMP), RFC 1157, http://www.ietf.org/rfc/rfc1157.txt.

[5] The Internet Engineering Task Force (IETF), http://www.ietf.org/.

[6] Jae-Jo Lee, Choong Seon Hong, Joon-Myung Kang, and James Won-Ki Hong, "Power line communication network and management in Korea," International Journal of Network Management (IJNM), Vol. 13, Issue 6, Special Issue, November/December 2006, pp 443-457.

[7] Joon-Myung Kang, et al. "Design and Implementation of Network Management System for Power Line Communication Network," IEEE International Symposium on Power Line Communication and its Applications (ISPLC 2007), Pisa, Italy, March 26-28, 2007, pp. 23-28.

[8] DS2, http://www.ds2.es/.

[9] Intellon, http://www.intellon.com/.

[10] Xeline, http://www.xeline.com/.

[11] Panasonic, http://www.panasonic.com/.

[12] OPERA (Open PLC European Research Alliance), http://www.ist-opera.org/.

[13] HOMEPLUG, http://www.homeplug.org/

[14] Xeline, Xeline EMS System Manual, 2006.

[15] OPERA, Opera System Specification Part 2 version 1.0, 2006.

[16] HOMEPULG, HomePlug Access submission of IEEE P1901 Draft Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications, June 4, 2007.

[17] Management Information Base for Network Management of TCP/IP-based Internets: MIB-II, RFC1213, http://www.ietf.org/rfc/rfc1213.txt.