전력절감 그린어뎁터를 이용한 스마트홈 전력 통제시스템

유승재* · 박희동* · 김송강**

요 약

오늘날 우리는 후대에 아름다운 지구를 보호하고 풍요로운 지구를 후손에게 물려주기 위해 많은 나라에서 스마트그리드 정책을 적극 지원하기 위해 많은 자원을 투입하고 있는 실정이다. 또한 스마트 그리드의 개념을 적용한 스마트홈 구현에 대한 요구도 급속히 증가하고 있다. 그러나 현재 90% 이상을 차지하고 있는 기존 주택에 대한 스마트홈의 구축은 비용문제 및 추가 공사가 이루어져야 되는 등의 문제로 이루어지지 않고 있으며 오로지 신규 공공건설 주택에 집중되어지고 있는 실정이다. 본 연구에서는 추가공사 및 건축 없이도 기존 주택을 스마트홈으로 구축할 수 있는 솔루션을 제공하고 있다. 이 기술은 대기전력을 약 800mW에서 약 20mW로 획기적으로 줄일 수 있는 기술을 제공하고 있다. 본 기술의 구성은 주IC의 전력을 차단하고 교류 입력부에 위치한 최소 소자의 전력소모만 이루어지도록 구현하여 대기전력을 약20mW가 되도록 초절전 스마트홈을 구현하였다. 또한 스마트폰을 이용한 전력제어 및 각 가전제품의 소비전력을 확인할 수 있도록 스마트폰 어플을 이용할 수 있도록 구현하였다.

A Study on Smart Home Power-Control System with Power-Saving Green Adapter

Seung-Jae Yoo* · Hee-Dong Park* · Song-Gang Kim**

ABSTRACT

Today we have an obligation to pass the beautiful earth and enrich people's lives to next generations. According to the keynote, governments have a lot of resources to support the smart grid policies. Also the demand of the implementation of smart home applied the concept of smart grid is increasing rapidly.[3][4] But the construction of smart home is centered on a new public housing except the pre-existing house which is counted for most of more than 90% of total. In this study, we suggest the implementation solution to make smart-homelike for the pre-existing houses without additional wiring or construction. We develop the technology reducing the unnecessary standby power 800mW to 20mW drastically. If we apply this technology, by the power off of main IC the actual power depends on the consumption of minimal devise located on the AC input side. Then the standby power becomes approximately 20mW(110ac)..

Key words: Smart-Home, Green Adapter, Power Control System, PCAP, PMA.

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* 중부대학교 정보보호학과
** 중부대학교 정보통신학과(교신저자)

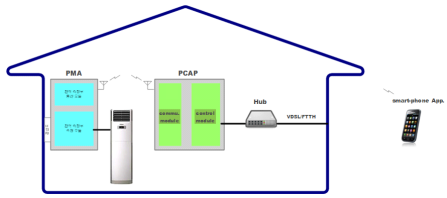
1. Introduction

Worldwide this is going to continue the optimization of power consumption and energy saving efforts through low-power electronic products development, smart grid, smart building and home-automation technologies[1][2]. These technologies can be adopted easily for new product or new apartment houses (or buildings). But it is very difficult to apply to existing houses or individual residences, even if applied to the high cost is required. In this study, we implement the power measurement adapter (PMA) and power control access point (PCAP) device to reduce power loss which can be adopted easily for new housing(building) as well as the existing house(building). The implemented device consists of PMA and PCAP. Then PMA is mounted in a home outlet and the electronics power cable is connected to PMA[5][6]. PCAP is connected to the home incoming VDSL/FTTH network hub using the ethernet cable. A user can be decided whether or not power off the PMA using a smart-phone application S/W.

2. Operational Concept

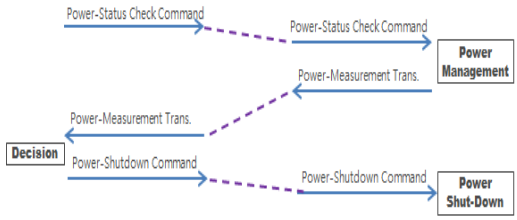
From the outside you can see the power consumption of home electronics which are attached to PMA through the smart-phone application (fig.1).

In the confirmed power measurements, if we check the unnecessary power consumption of some specific electronic products, power-down command is sent via the smart-phone application.



(Fig. 1) Concept of smart home power control system

As shown on figure 2, the PMA which received the command performs the shutdown to the supply of electronic products which connected to the adapter.



(Fig. 2) Flowchart of the control machine

PCAP communicates with smart-phone application on Wi-Fi network of WISP. And PCAP communicates with PMA via ZigBee.

3. PCAP Server S/W Design

3.1 PCAP

PCAP has the naming function, power ON/OFF, trap event processing, boot-on function by outlet or group. And in software PCAP has the function to collect and control the PMA data using ZigBee or Bluetooth. Also it carries out the access authentication process, boot-on server update, the response processing according to internet remote terminal requests and the session connections and maintenance function considering periodic polling

PMA has the functions to correct the real-time voltage, current and temperature data. It maintains the real outlet state (On/Off) information. It transfers data periodically (Max. 1 per second) and transmits trap event (alarm over voltage/current/temp.). Also it carries out the transmission and receipt of signals via ZigBee or Bluetooth, and power On/Off by the control signal.

3.2 Server

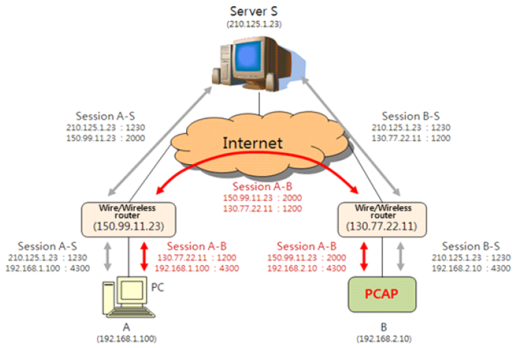
It provides for information and functionality to maintain the session between two points. For this, it should be considered the STUNT, TURN, NUTSS, NATBlaster etc. using the hole punching. Initially, it provides for a simple form of hole punching capabilities to maintain the session simply.

The provided information is PCAP serial number (SN), e-mail address and phone number. At the time of initial registration and connection, transfer is in progress without encryption. At the time of remote access, encrypted transmission and reception are in progress (current key considering phone number) since it can lead to serious problems if the data, IP address and serial number are leaked.

And server receives a predetermined port (SVR_PORT). Alarm information of PCAP is to support the push server function to be passed to the user using the push functions.

3.2.1. Server Stored Information: DB server contains the sever information, serial number, session information (IP address and Port number), NAT type, ID/password (authentication code) and phone number(key).

3.2.2. Session Establishment with Client and PCAP: Now we check the sever functionalities to support the session establishment between the client and PCAP.



(Fig. 3) Network connection structure

As shown on fig.3 the session information is each IP address. It is composed of the pair of port number. Server S maintains the session with PCA. PCAP sends the connection request to maintain the session with server S. Receiving the request to connect to PCAP from client, then server S sends to A session information of B (Public endpoint (130.77.22.11: 1200) and Private endpoint (192.168.2.10: 4300)). Also it is to be connected B to A while sending session information of A (Public endpoint (150.99.11.23: 2000) and Private endpoint (192.168.1.100: 4300)) to B. At this time, server sends the predictive information of each other depending on the NAT types.

When A receives session information of B from server S, it will try to connect to B. It retries several times until connection succeeds. Upon termination of connections and processing with A, PCAP tries to make a periodic maintenance session with server S again.

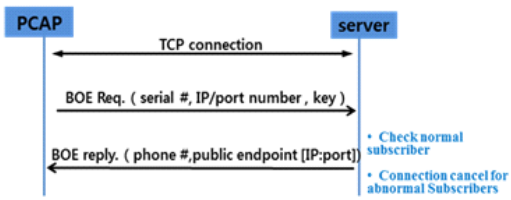
3.3 Control and monitoring

We see the manual registration procedure, Boot-On Enrollment of PCAC, PCAP connection and ID/Password registration process of Client.

First register the server PCAC (Serial number and Registration ID). Subscribers register their ID

in PCAP and register the registered PCAP user (Phone number).

3.3.1. Internet-based control and monitoring: The figure 4 below is the procedure of PCAP log-in (Boot-On Enrollment of PCAC) which provides services and verifies the proper device to use



(Fig. 4) Boot-On Enrollment of PCAC

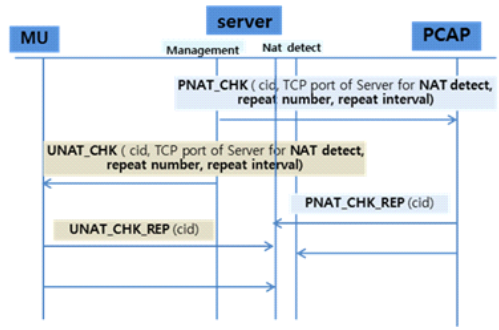
PCAP tries to make a periodic maintenance session with server S (SH_REQ/SH_REP). In fact, at the end of the procedure the BOE, PCAP should keep the session with server while communicating periodically. Server sends the Server Hello Request (SH_REQ) through the promised port (SVR_PORT), and then server replies Server Hello Reply(SH_REP) so that maintain the address translation table information in NAT.

When PCAP finishes the connections and services with the Client, it starts the BOE procedure again, and then session maintenance procedures will proceed.

3.3.2. Session maintenance with Server periodically: After BOE procedures, PCAP must maintain the session while communicating regularly with server. PCAP send Server Hello Request(SH_REQ) to server through the promised port of the server(SVR_PORT), and server responds with the Server Hello Reply(SH_REP) in order to maintain the address translation table information in the NAT. Also when the connecting service is complete to the client PCAP will start the BOE procedure again, and then the session maintenance procedures will be maintained.

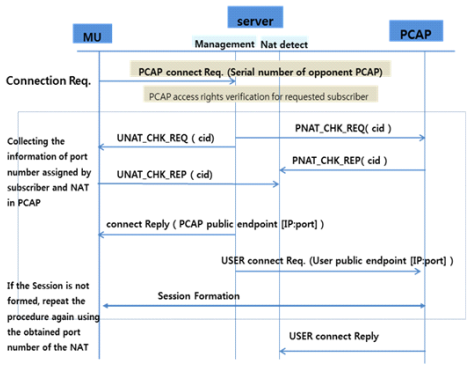
3.3.3. NAT Check Procedure: This procedure is to know the NAT type of private network where the client located, and especially to increase the probability of connection despite of the difficulty in p2p connection on the symmetric cone type NAT.

As shown on figure 5, IP address is assigned to the PCAP or subscriber by the NAT, and then it is used uniquely to interface with TCP/IP that is created later. Thus, for the connection with PCAP and subscriber it needs to predict the port number which is assigned by the NAT. It is necessary for these prediction to perform the procedure for finding out the port allocation method of NAT.



(Fig. 5) NAT check Procedure

PCAP and subscribers transfer the NAT_CHK_reply through the NAT_detect_ TCP port which specified by NAT_CHK_ Req, and they are depending on the number of repeats and the repetition interval which are required by NAT_CHK_ Req. PCAP and subscribers transfer the failure through NAT CHK if it is unable to use the NAT_detect_TCP port specified by NAT_CHK_Req.



(Fig 6) Remote Connection Procedure

The Figure 6 shows the remote connection procedure among the PACP, Sever and User.

3.4 S/W Block Structure of PCAP

As the interface for the operation, it supports USB, and sets the PCAP behavior in connection to the PC's GUI.

The software on PCAP for p2p connections with user provides the various functions; the connection with the server and the p2p connection with user, API for sending and receiving messages with a user to top application, CLI to set the PCAP behavior (command line interface). Also it provides the USB interface and WiFi interface.

Sever supports the p2p connection between user and PACP. p2p connection control of server supports dynamic IP (or public IP) through the router of PCAP and user. The protocol used to connect control is the TCP protocol. The server provides the command to register (or remove) the serial number of PCAP and user's phone number to the operator as well as the currently connection information. Also the user information stores in the disk, so that maintains the configuration information at the same time of re-execution of the application.

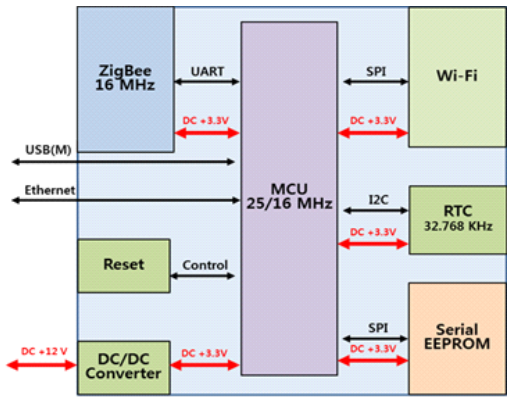
TCP interlocking block supports the specification of the linkage between PCAP and USER based on the PCAP and PMA specification.

For these supports, there are sub blocks such as P2P connection control, PCAP register and NAT behavior detection. The p2p connection control unit receives a connection request from PCAP and the user, and then makes connection. PCAP registration unit takes receipt from the device registration, and monitors the PCAP connection status. NAT behavior detector unit PCAP detects whether PCAP and user via a router or not, and if so then estimate the p2p connection port number to which the router assign. CLI block provides the operator with a command line interface to control the server. Timer block monitors the connection status in server periodically, and by looking for any abnormalities for connection, it attempts to connect request again.

4. PCAP and PMA H/W Design

4.1 PCAP H/W Design

PCAP receives the power value which is collected from the PMA ZigBee (2.4 GHz) and then transfers this information to the User(smart phone or PC) using LAN or Wi-Fi (2.4 GHz) network in conjunction with the network sever. Also user controls PMA in the reverse order. (fig. 7)



(Fig. 7) PCAP Entire Block Diagram

4.1.1. Power Block: Using a DC / DC converter with up to 95% efficiency it can supply 2A electric current continuously and built-in output short and temperature protection functions. Also it supplies stable output voltage in case of the load variation and input variations.

4.1.2. Wi-Fi Block: Wi-Fi communication is the end-to-end communication by default between AP(access point) and User(laptop or smart phone. PCAP is equipped with Microchip's integrated WiFi module (MRF24WB0MB), and it uses WiFi (2.4 GHz) network to communicate at data speeds of up to 1Mbps.

High-frequency output is 10dBm, and Receive Sensitivity is -91dBm, and Current is consumed 154mA and 85mA for transmission and reception respectively.

Also it transfers the information to the User in conjunction with the network sever, and User controls PMA in the reverse order.

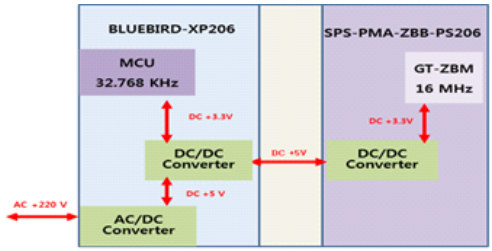
4.1.3. Reset Block: Processor-only initialization chip(APX823-29WG-7T) was equipped to operate safely by initializing the micro-controller which it delays initialization signal 10ms after power ON.

4.1.4. MCU: In synchronization with the clock of 16MHz micro-controller is operated, it receives data collected from PMA by communicating with ZigBee module. The collected data is stored at serial storage (U7) through asynchronous communication with micro-controller. Then micro-controller in conjunction with a smart phone on WiFi network controls power ON/OFF of appliances and electronic devices connected to the PMA through ZigBee module. Also in other regions, the data stored on the network server can be checked and retrieval via Ethernet.

4.1.5. Serial Flash EEPROM: It is a data storage (U7) which saves data collected form PMA such as power consumption data, human detection data. Select signal of the storage, the clock are authorized to pin1 and pin6 respectively. And pin5 authorizes the power consumption and human detection data.

4.2 PMA H/W Design

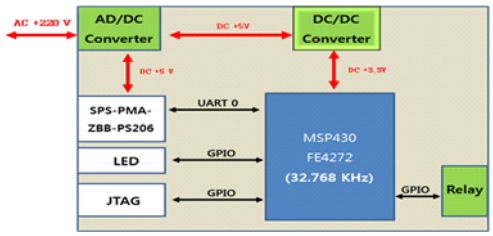
PMA(Power Measurement Adaptor) is used to connect to the 220v outlet of home or office and it is responsible for the transfer function via ZigBee(2.4GHz) communication for PCAPs which measure and collect the power consumption of household appliances. (fig. 8)



(Fig. 8) PMA Entire Block Diagram

This receives input from the 220v outlet to AC220v, and converts to DC+5v at AC/DC Converter. Then it supplies DC+5v power to DC/DC Converter in BLUEBIRD-XP206 and SPS-PMA-ZBB -PS206 board, and DC/DC Converter converts the received power DC+5v to DC+3.3v and supply it to each circuit on BLUEBIRD-XP206 and SPS-PMA-ZBB- PS206 board (fig. 9).

4.2.1. BlueBird-XP206: It receives input from the 220v outlet to AC220v, and then convert to DC+5v at AC/DC Converter and it supplies DC+5v power to DC/DC Converter. DC/DC Converter converts the received power DC+5v to DC+3.3v and supplies it to the control device MCP430.

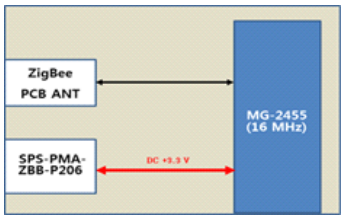


(Fig. 9) BlueBird-XP206

Also it is converted to DC+5v at AC/DC Converter, then supply it to SPS-PMA- ZBB-206 board. MSP430 controls the relay to supply (or break) remotely through ZigBee(2.4GHz) communication.

And it measures the power consumption of household appliances and transfers it to PCAP using ZigBee module on SPS-PMA- ZBB-206 board.

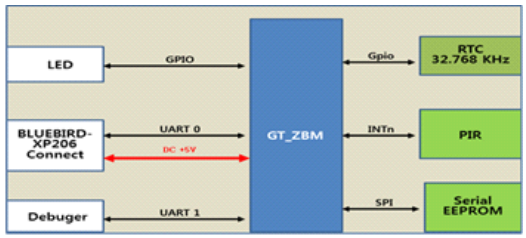
4.2.2. GT-ZBM(ZigBee): It is a ZigBee communication module using communication chipset(MG-2455) as shown on figure 10.



(Fig. 10) GT-ZBM Block

4.2.3. SPS-PMA-ZBB-PS206: It receives DC+5v from BLUEBIRD- XP206 board for supplying the power on SPS-PMA-ZBB- PS206 board(fig. 11). It stores the Real Time Data (RTC, real time clock), Human Detection Sensor Data (PIR Passive. Infrared Ray) at Serial EEPROM and transfer to PCAC through ZigBee.

In order to improve the function of the board, it can be changed the board's firmware through Debugger port.



(Fig. 11) SPS-PMA-ZBB-PS206

5. Results

Today we have an obligation to pass the beautiful earth and enrich people's lives to next generations. The demand of the implementation of smart home applied the concept of smart grid is increasing rapidly. But the construction of smart home is centered on a new public housing except the pre-existing house which is counted for most of more than 90% of total. In this study, we suggest the implementation solution to make smart-homelike for the pre-existing houses without additional wiring or construction. In this study, we have developed the green IT technologies which dramatically reduce the standby power so as to reduce the existing 800mW or more to 20mW possible.

As a result of this study, before the advent of smart grid in earnest, we adopt this easily for the pre-existing houses (or buildings). We provide AP and the adapter inserted into the outlet together to save the power, and also we implement AP to be able to assigns IP address for each adapter. It gives the power saving features as well as accumulated power to each outlet adapter, so that it increases the interest in electricity savings.

In line with recent trends, by implementing WiFi communication capabilities for AP function, it can be connected to smart phone application to manage and control AP and adapter. Also this

technology reduce the unnecessary standby power 800mW to 20mW drastically.

In this technology, by the power off of main IC the actual power depends on the consumption of minimal devise located on the AC input side. Then the standby power becomes approximately 20mW (110ac).

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[저 자 소 개]

유 승 재 (Seung-Jae Yoo)

1988년 2월 동국대학교 이학사
1990년 2월 동국대학교 이학석사
1998년 2월 동국대학교 이학박사
1997년 3월 ~ 현재 중부대학교 정보보호학과 교수

email : sjyoo@joongbu.ac.kr

박 희 동 (Hee-Dong Park)

1991년 2월 포항공대 공학석사
1999년 2월 경상대학교 공학박사
1982년 3월~1994년 2월 ETRI
1999년 3월 ~ 현재 중부대학교 정보통신학과 교수

email : hdpark@joongbu.ac.kr

김 송 강 (Song-Gang Kim)

1987월 2월 동국대학교 이학사
1989년 2월 동국대학교 이학석사
1994년 3월 오사카대학 공학박사
1995년 3월~2000년 2월 현대전자
2000년 3월 ~ 현재 중부대학교 정보통신학과 교수

email : kimsg@joongbu.ac.kr