Flood Transmission based Protocol for Home Automation System via Power Line Communication

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Abstract

There are many researches and development involving the use of power line as data transmission medium. With multiple power outlets in almost every room in every house, the power line is the most pervasive network and the largest infrastructure available. The aim of this project is to deploy this infrastructure in designing a home automation system. This paper presents a method to develop a home automation system using the AC (alternating current) power line to establish a network between main controlling unit and client units with a proprietary designed power line communication (PLC) protocol. The designed protocol has features such as multinode simplex communication, flood transmission and even parity error detection. The protocol is successfully implemented and tested in a home automation system consisting of one main controlling unit and three client units. Each client unit is able to control three electrical devices. Multipoint of receiver units can be controlled (On / Off) by the main controller unit sending command data using power line as transmission medium to the corresponding devices.

Keywords: Power line communication, multinode communication, flood transmission, parity checking.

I. INTRODUCTION

Digital communication over the power line called power line communication (PLC) has become an excellent opportunity for the energy providers (utility corporations) to implement new services, both for the utilities and for their customers. As power line network is the most enormous and wide-spread network with huge, unmatchable scale, PLC will become more important in modern communication technology, and would possibly become the replacement for present telephone network, cable TV network and residential internet network eventually [1]. This "four in one" system will hugely reduce the initial investment of network construction [2]. Smart home technology is one of the specialized applications where power-line communication can be a key technology.

By considering these advantages of power line as a transmission medium, a new network protocol is designed to suit the needs of a home automation system which is sustainable in the noisy environment of power line communication. The question is; what does a home automation system need? Firstly, home automation system needs more than one electrical device to be controlled at a time. Otherwise, consumer would not be delighted. Thus, the designed protocol must include multinode capability; which means a main controlling unit can simultaneously support multiple nodes.

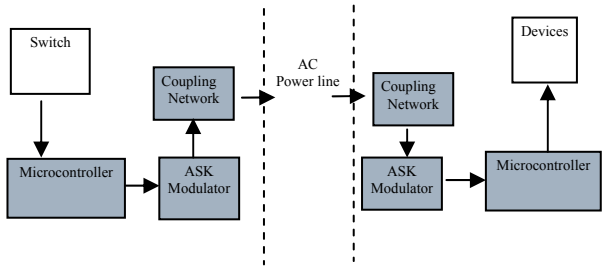

Figure 1. **Block diagram of home automation system via power line**

Figure 1 shows a block diagram of a basic home automation system via power line. The main controller unit, consisting of a microcontroller, will send command data using power line as transmission medium to control the corresponding devices. The built system has one main controlling unit and three client units. Each client unit is able to control three electrical appliances. Hence, for this particular system, nine devices can be controlled at a time. Commands

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from users are set using slider switches and sent out in packets. As the focus of this system is device control, a master and slave relationship between main controller and client units is chosen.

Secondly, as mentioned, it will be more user-friendly if the home automation system can send command to the entire target clients at once. If the user has to switch on an electrical device one by one, it will be very troublesome. Therefore, the designed network protocol should support multitasking capabilities. Power lines were not designed for data communications and exhibit highly variable levels of impedance, signal attenuation and noise. In the study of noise sources of residential power line, one of the sources generates impulse noise in synchronism with the 60 Hz power frequency [3]. Thus, Flood Transmission and parity error detection are implemented in the design to overcome these problems.

II. NETWORK PROTOCOL DESIGN

By taking into considerations the nature of PLC, a network protocol is designed. This network protocol is specially designed for home automation system. The details of this network protocol will be discussed in the following sections.

A. Simplex multinode communication

The network protocol adapts simplex multinode communication. In this home automation system, master-slave relation and star network topology are used. Therefore, one-way communication can be implemented. The main controlling unit will be the one transmitting the packets, while the client units will only receive the packets. The main controller needs no response from client units. However, to make sure the packets from the main controller reach the client units, a mechanism such as flood transmission is used to support the network protocol.

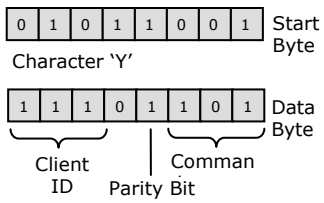
In multinode communication, network protocol supports more than one node in the network. It is not a one-to-one master-slave relation. There can be more than one slave in this case. In this network protocol, a maximum of three nodes are supported. Each node represents one client unit. A single client unit is capable of controlling three devices. Therefore, a total of nine devices can be controlled. For practical implementation, a single node is suggested to be placed in one area. For example, a single node in living room, a single node in bedroom and another single node at the porch.

B. Frame format

A packet contains two bytes of data. The frame format is shown in Figure 2. The first byte is the start byte which will indicate the start of the sent data. The second byte is the data byte. Client units will start to receive data after it senses start byte. ASCII character of 'Y' is chosen as the start byte. The bit pattern of start byte, "01011001", will never occur in the next data byte. Otherwise, receiver or client unit will find it hard to differentiate start byte and data byte. Data byte consists of client ID field, parity bit and command field. Bit 4 of the data byte is a redundant bit which does not contain information. It will always remain as binary 0. For parity error detection, even parity is used in this network protocol. It can detect single bit error.

By referring to Figure 2, it can be seen that client ID field is the first 3 bits of the data byte while the command field is the last 3 bits of the data byte. In client ID field, the first bit represents client 1, second bit represents client 2 and the third bit represents client 3. Binary 1 in this field means the packet is sent to the corresponding client while binary 0 means the packet is not sent for the client. Example in Figure 3 shows the packets for client 1 and client 2.

Figure 2. **Frame format**



In command field, the first bit represents device 1, the second bit represents device 2, and the third bit represents device 3. Binary 1 in this field means the particular device will be switched on. On the other hand, binary 0 means the particular device will be switched off. Example in Figure 3 shows that device 1 and device 3 are switched on while device 2 is switched off. Multitasking can be reached when the packet is sent to more than one client.

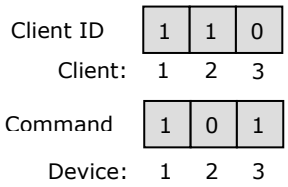


Figure 3. **Client ID field and command field**

The corresponding client units will execute the same command. For example, client ID field of "111" and command field of "111" will switch on all the devices in all the three client units simultaneously. It is more user friendly as users do not need to send command to client unit one by one if the command is similar.

C. *Flood transmission*

Due to the harsh environment of PLC, during packets transmission, about 1 out of 20 packets will be lost. To ensure the client receive the packet, a number of packets are sent repeatedly. Thus, lost packet can be substituted by cloned packets. This is the flood transmission, where the main controller will flood the transmission with a series of cloned packets during transmission. In this network protocol design, 10 similar packets will be sent out as flood transmission. After a packet is sent, transmitter will take a time delay before sending the next packet. It provides sufficient time for the receiver to process the incoming packet before receiving the next packet. The data packet flow is shown in Figure 4.

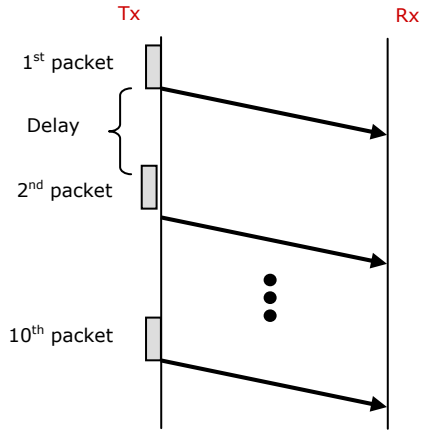


Figure 4. **Flood Transmission format**

III. METHODOLOGY

As mentioned before, the main controlling unit and client units are connected using star topology (see Figure 5). Once a client is chosen, the command is given by adjusting the slider switch. Button is pressed to send the command data. Light Emitting Diode (LED) at the main controller will toggle after the button is pressed. The target client units will response to the command. These are the basic operation of the home automation system. This system can be implemented in two major part, namely software and hardware implementations.

A. *Software implementation*

In software implementation, it will be mainly the programming of PIC16F877A microcontroller [4]. MikroC from mikroElektronika is used to develop the programming for the microcontroller in this home automation system because it provides rich features [5]. The microcontroller, as the 'brain' of the system, is responsible of processing network protocol, which consists of transmitting packets and receiving packets. Besides, the microcontroller will also do the job of receiving users' inputs and executing commands.

B. *Hardware implementation*

Hardware implementation involves the circuit design of home automation system prototype. There are two types of circuits in this system. One is for the main controlling unit while the other is for client units. The amplitude shift keying (ASK) modulation is carried out using Philips TDA5051A ASK modem [6]. The main controlling unit and client units have the same schematic for ASK modem. In this prototype, some analogies will be used. At the main controller, Dual In Line (DIL) switch and a button will represent the user input mechanisms. Furthermore, a green LED indicates data sending status. While at the client side, LEDs are used as analogies of the electrical devices which were being controlled. Figure 5 illustrates the hardware prototype of the home automation system via PLC in star topology.

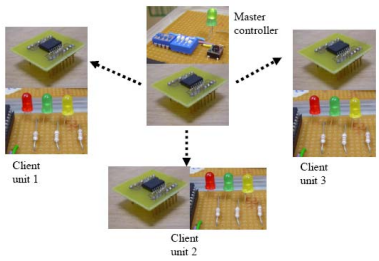


Figure 5: Hardware prototype of home automation system via power line in star topology

IV. DISCUSSION

The developed home automation system uses the specially designed network protocol. The network protocol has features such as simplex multinode communication, even parity error detection, flood transmission and supports multitasking. The system is able to connect up to 3 client units which can control up to 9 electrical devices in total. Currently, X10 protocol has a monopoly on the power line home automation system in the market. However, the main disadvantage of the X10 technology legacy is the fact that it has very limited capability in terms of both

speed and intelligence. Besides, X10 technology does not have error handling capability.

Compared to X10 technology, the designed network protocol data rate is 1200 bps which is 20 folds of the X10 speed, 60 bps. In terms of error handling, the designed network protocol uses even parity error detection to prevent single bit error and flood transmission to prevent lost packets. Amplitude Shift Key (ASK) modulation with 115.2 kHz carrier frequency is used to prevent interference from the 60 Hz power signal. While in X10, it uses the 60 Hz power signal in its zero-crossing transmission method [7]. With 115.2 kHz carrier frequency, attenuation from different load such as computers and television sets could be avoided. The system is tested with several computer plugged in along the power line. The comparison between X10 and the designed network protocol is shown in Table 1.

TABLE 1: COMPARISON BETWEEN X10 AND DESIGNED NETWORK PROTOCOL

X10	DESIGNED NETWORK PROTOCOL
60 BPS	1200 BPS
NO ERROR HANDLING CAPABILITY	EVEN PARITY ERROR DETECTION AND FLOOD TRANSMISSION
60 HZ CARRIER FREQUENCY	115.2 KHZ CARRIER FREQUENCY
ZERO-CROSSING TECHNIQUE	ASK MODULATION
MULTINODE SUPPORTED	MULTINODE SUPPORTED
HALF DUPLEX COMMUNICATION	SIMPLEX COMMUNICATION
1 CLIENT UNIT CONTROLS 1 APPLIANCE	1 CLIENT UNIT CONTROLS 3 APPLIANCES
SIGNAL WILL DETERIORATE WHEN PASSING BY MODERN ELECTRONIC EQUIPMENT, E.G. COMPUTERS	SIGNAL IS COMPATIBLE WITH DIFFERENT KIND OF LOADS AND MODERN ELECTRONIC EQUIPMENT

V. CONCLUSION

As a conclusion, a flood transmission based protocol for home automation system using power line communication is successfully developed and tested. The main controlling units will read inputs from users and the client units will execute the command from the users. There is no need for new wire or cable to be installed as power line is used as the transmission medium. Home automation system provides the feeling of comfort, security and convenience in people's daily life. Users can take full control of all the electrical appliances in their house through one main controller unit.

A reliable network protocol using simplex multinode communication and flood transmission is designed to establish the connection for the entire PLC network. This specially designed network protocol supports multitasking and even parity detection to minimize erroneous transmission on the noisy and high attenuation power lines. Continuing researches in this area include the implementation of an internet connection through PLC system using Asynchronous Digital Subscriber Line (ADSL) modem and its challenges.

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