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HOME APPLIANCES CONTROL SYSTEM BASED ON POWER LINE COMMUNICATION TECHNOLOGY

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ABSTRACT

Home automation is an integral part of modern life that helps to monitoring and controls the home electrical devices as well as other aspects of the digital home that is expected to be the standard for the future home. Home appliance control system enables the house owner to control devices such as stove, refrigerator, air-conditioner, and lightings remotely or monitoring the house status. Monitoring and control may be done by a personal digital device such as a laptop, PDA, telephone, or even a cell phone. One of the technologies well used by domestics to connect the home controller with the appliances is using the Power-Line Communication (PLC) protocol for data transmission. Inthis paper two types of home appliances PLC controller will be implemented based on the HomePlug Command and Control (HPCC) standard.

Keywords: PLC, Embedded System, Home Network.

I. INTRODUCTION

Nowadays, the rapid development of information technology has brought powerful changes to the structure of automation system, and makes people to set a higher request to security, comfort and efficiency of home environment. Intelligent household devices have become a research focus in home automation industry, for how to let television set, refrigerator, lightings, alarm sensor, and other home devices work efficient and easy to be used. Under such demand home appliances should not only operate by itself, but also with other devices together, i.e. they should be connected within a network for easy management.

Many accessing methods for controlling home appliances can be used, such as by hard wired line, telephone line, Ethernet cable, radio frequency, infrared, or powerline. Technically, they are divided in two types of networking techniques; the first one is data exchange between transmitter and receiver in a wireless way, i.e. Bluetooth, 802.15.4/ZigBee or Z-wave, the other networking alternative is based on fixed wire line i.e. telephone line, Ethernet cable and others. Power-line is a special media, which transport not only the AC power to devices, but also the multimedia or control data to and from the device; the benefits of using this media are the availability and quantity of electrical outlets in a house and no new wiring necessary for building the network [1 ~5].

Power -Line Communication (PLC) technology [6, 7] utilized the household electrical power wiring as the transmission medium. Using this technique for remote automation control in house requires no installation of additional control wiring. Originally, the application of PLC was mainly to secure the normal operation of the electric power supply system in case of malfunctions or faults through the instant exchange of information between power plant, substation and distribution center, thereby making this approach a competitive alternative to smart home networking, considering the benefit of its robustness, ready connectivity as well as availability.

II. PROTOCOLS IN THE PLC TECHNOLOGIES

To control intelligent home appliances the digital control signal will modulate an analog carrier signal, which will be propagated through the whole AC power grid at home on the same distribution system, therefore each receiver has its own "device address" that designates the owner of the control signal. These receivers may be either plugged into regular power outlets, or permanently wired in place. Figure 1 shows the typical power-line communication system, a PLC modem converts a data signal received from conventional communication devices, such as computers,PDAs, or Laptops in a form that is suitable for transmission over power-lines. In the other transmission direction, the modem receives a data signal from the power grids and after conversion delivers it to the communications devices.

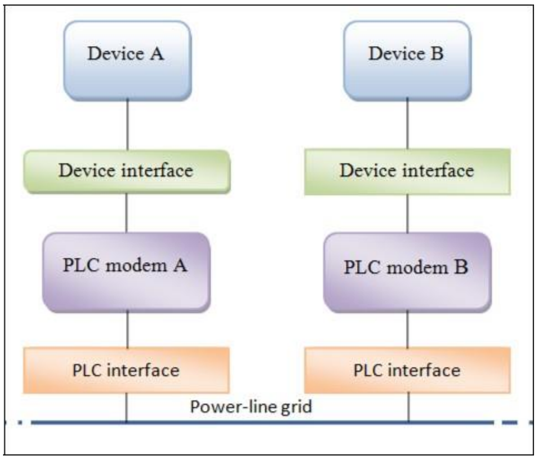

Fig. 1 Communication over power-line grid

The standards and technologies used in the PLC control schemes include X10 [8], CEBus [9], LonWorks [10, 11], Insteon [12, 13], HomePlug [14, 15], and some others. They are described as follows:

1. **X10** was developed in 1975 by Pico Electronics [8], is an international and open industry standard for communication among electronic devices used for home automation. In the X-10 protocol, transmissions are synchronized with the zero-crossings on the ACpower-line. A binary '1' is represented by a 1mS long burst of 120 KHz, near the zero-crossing point of the AC. A binary '0' is represented by the lack of the 120 KHz burst (fig. 2). The X10 protocol is quite slow, data rates are around 20 bits/s, so it takes roughly 3/4 secondto transmit a device address and a command. It lacks also the support for encryption, and can only address 256 devices.

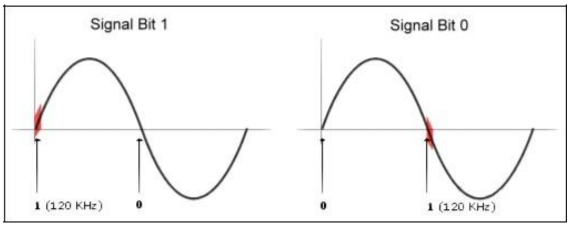

Fig. 2 Data format of X10 signal.

2. **CEBus** (Consumer Electronics Bus) also known as EIA-600, was released in September 1992 by the Electronic Industries Alliance (EIA) [9], is a set of electrical standards and communication protocols for electronic devices to transmit commands and data. It is suitable for devices in households and offices to use, and might be useful for utility interface and light industrial applications.

   The CEBus standard uses spread spectrum modulation on the power line. A binary '1' is represented by a 100 microseconds long burst, and a binary '0' is represented by the absence of burst that lasts 200 microseconds, the average data rate is about 7,500 bits/s.

   CEBus supports a flexible topology, thus a device may be located wherever convenient, and the control is distributed among the CEBus appliances and media routers (fig 3).

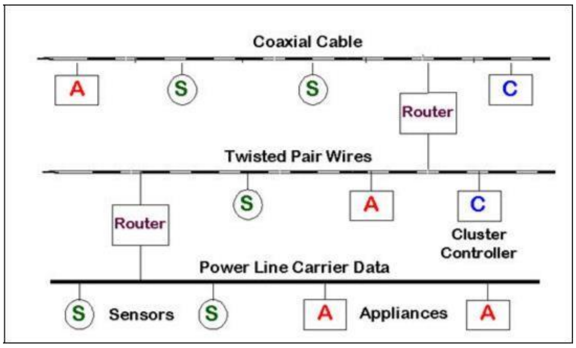

Fig. 3 Example of CEBus topology [9]

3. **LonWorks** is a networking platform specifically created to address the needs of automation control in industrial, home, transportation, and buildings systems such as lighting and HVAC. The platform is built on a protocol LonTalk created by Echelon in 1999, and is defined by ANSI Standard ANSI/CEA 709.1 [10, 11]. The LonWorks is an open, but proprietary technology and is not subject to use power line as media. Communication between devices may be either peer-to-peer (distributed control) or master-slave (centralized control) (fig. 4).

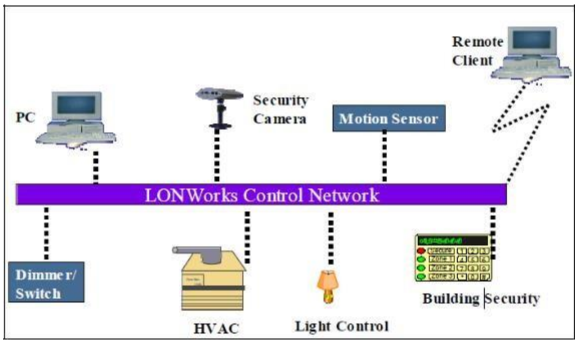

Fig. 4 Example of LonWorks network

4. **INSTEON** is a dual-mesh RF & power line home automation networking technology designed by SmartLabs technology in 2005 [12, 13]. This technology was designed specifically to address the inherent limitations in the X10 standard but also toincorporate backward compatibility with X10. Under the network topology, all Insteon devices are peers, meaning each device can transmit, receive, and repeat any message without requiring a master controller or routing software (fig. 5). The data rate is up to 13,165 bits/s on wire and 38,400 bits/s on air.

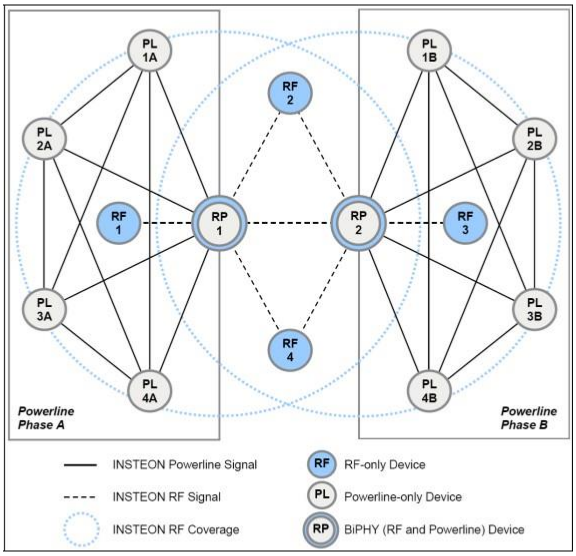

Fig. 5 Network topology of INSTEON [13]

5. HomePlug Command and Control (HPCC) standard is developed by the HomePlug Powerline Alliance for home/building automation, remote monitoring and control, the white paper version 1.0 was released in 2008 [14, 15], which contains a PHY and MAC layer in this version, but will be expanded to network and host layers.

   Fig. 6 shows the PHY (Physical) block diagram of HPCC standard, which is the first layer in the seven- layer OSI model. It defines the electrical, mechanical, procedural, and functional specifications for activating, maintaining and deactivating the physical link between communicating network systems.

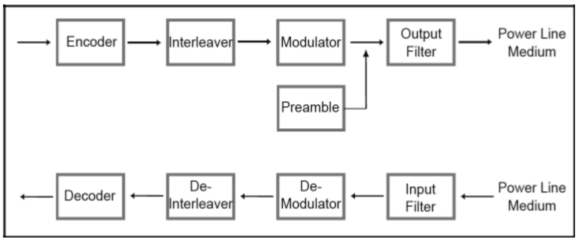

Fig. 6 PHY block diagram of HPCC [15]

The HPCC uses a patented Differential Code Shift Keying spread spectrum (DCSK) modulation on the narrow-band power line. The data transfer rates is 7.5Kbps on the PHY Level. It will work also with high-speed broad-band networking, such as HomePlug 1.0, and HomePlug AV.

III. IMPLEMENTATION

From the above descriptions the HomePlug C&C might be the most recent and more advanced for home automation system. To implement this technology for home automation a PLC modem (IT700) from Yitran was selected [16], the main reasons are:

1. IT700 is a fully integrated PLC microcontroller for command and control applications on a single chip, which incorporates an extremely reliable PHY, line driver, 8051 mcu core with 256 KB flash ROM for protocol stack and firmwares, 16KB RAM, and 24 GPIOs (fig. 7).

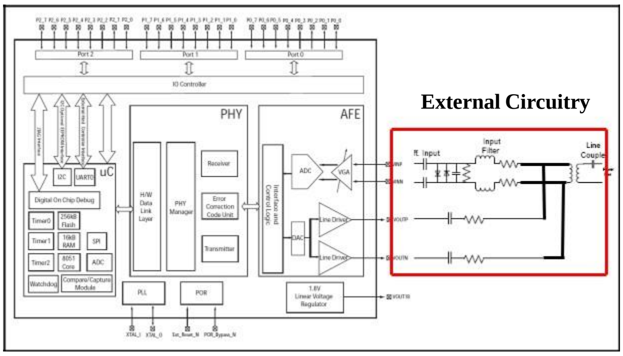

Fig. 7 IT700 block diagram [16]

2. IT700 follows the HomePlug Command and Control standard and uses PLC ready transceiver technology, which is high immunity to signal fading, phase/ frequency distortion, various noise characteristics, and impedance modulation.
3. Yitran offers complete reference design and Plug In Module (PIM) with integrated Analogue Frond End (AFE), line coupler and power supply interfaces for quick application prototyping and development (fig. 8).

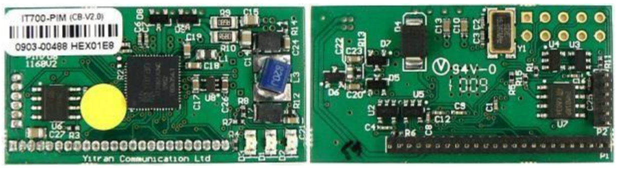

Fig. 8 IT700's Plug In Module [16]

4. The IT700 incorporates reliable Physical Layer (PHY), high-performance Data Link Layer (DLL) and Network (Y-Net) protocol [17]. The Network Layer (NL) is implemented using an advanced and compact adaptive routing and automatic addressing mechanism, enabling optimal and simple powerline communication (tab. 1).

Tab. 1 Y-Net protocol stack firmware and OSI Layers

	Application	Upper Layers
	Presentation	
	Session	
	Transport	
Y-Net protocol stack firmware	Network (NL)	
	MAC	Lower Layers
	Physical (PHY)	

Since the IT700 PIM supports up to network layer only, all other above layers must be executed by other processor, therefore in the PLC control network two types of controller were implemented in this work, one is an embedded main controller with powerful microprocessor used for human operation (fig. 9), and the other is device controller with simple and low cost microprocessor used for control or monitoring home appliances (fig. 11).

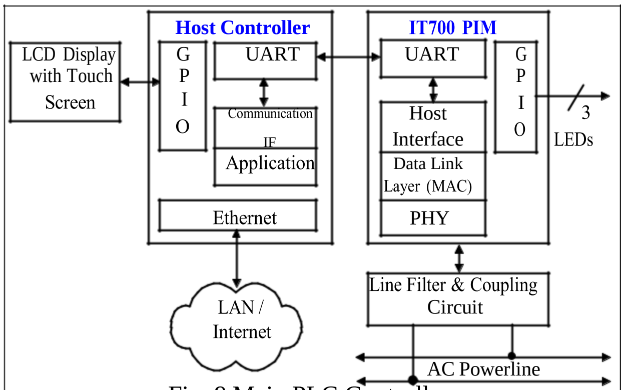

Fig. 9 Main PLC Controller

The main PLC controller is equipment with a touch screen LCD display and is realized using a Mini2440 single-board computer from Friendly ARM (fig. 10) [18]. This board is based on the Samsung S3C2440 microprocessor, which features a 16/32-bit RISC ARM920T core, includes the following components: separate 16 KB instruction and 16 KB data cache, MMU to handle virtual memory management, LCD controller and touch screen interface, NAND flash boot loader, UART, DMA, timers with PWM, RTC, 10-bit ADC, camera interface, AC97 audio codec interface, SPI, IIC-BUS, IIS-BUS, USB host/device, and SD card interface.

This board utilizes all features of S3C2440 microprocessor and has an Ethernet interface for LAN/Internet access. The board runs under Linux 2.6.29 or WinCE.NET 5.0 operating system, which makes the implementation of application software easier and quickly. In this work the WinCE OS were be selected, which is supported by Microsoft's Visual Studio 2008 on window machine. An Internet web page was developed also for remote user to access the PLC home network.

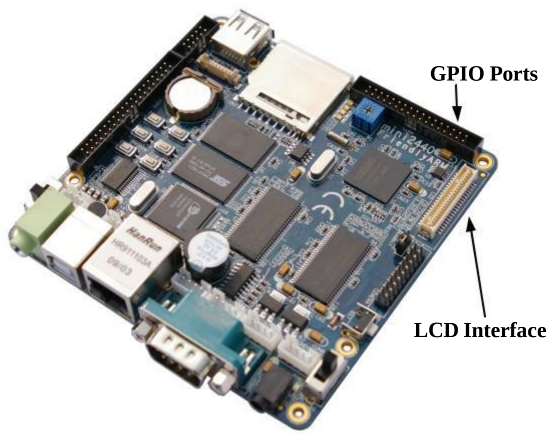

Fig. 10 Mini2440 single-board computer [18]

The device PLC controller may equipment with electronic switch circuits or various sensors but without Ethernet interface, since all data communications are pass through the power-line. The electronic switch circuit (SSR) will be used for control home appliances, such as lighting, heater, fan and etc. Varity sensors can be used to detect status of home devices or to monitor environmental data such as temperature and humidity. The microprocessor used in the host controller can be any type with some GPIO ports and UART interface to be connected to IT700 PIM.

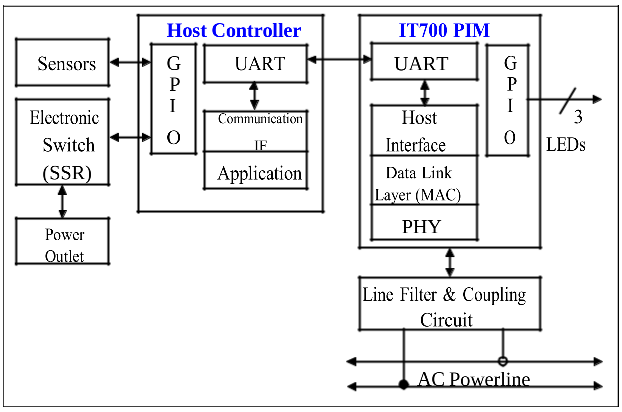

Fig. 11 Device PLC Controller

IV. EXPERIMENT RESULTS

This section will describe experiment results of the above realizations of home PLC controller. The test system consists of a main PLC controller and several device PLC controllers (fig. 12) . User can touch the LCD screen on the main controller and select the button to switch the corresponded device on or off or adjust the lighting brightness (fig. 13).

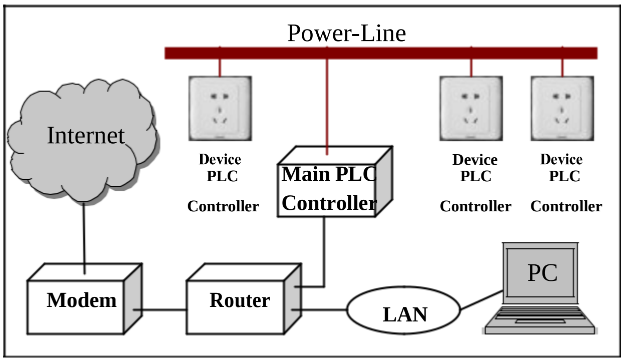

Fig. 12 General home PLC control system

Figure 13a is a user's interface on the main PLC controller, after the room is selected, the lower part of the screen will show all home electrical devices in this room, and then the user can check or uncheck the device to be controlled or the sensor to be monitored. After the "send" button is touched, the main PLC controller will send the required commands to those devices or sensors via the homepower-line, and receive response data.

Fig. 13a Control menu on main PLC controller

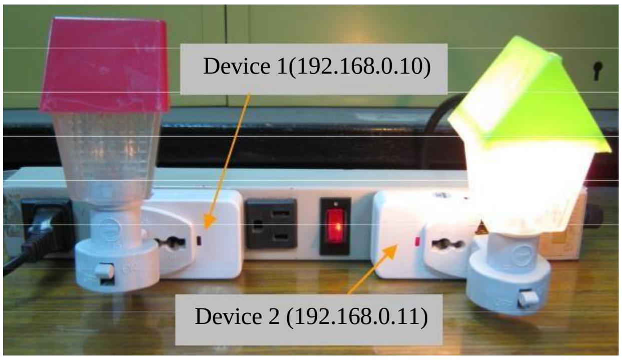

Fig. 13b Lighting control

Through the main controller the room temperature and humidity measured data can be retrieved also from remote user via Internet browser. After remote user connects this main PLC controller via Internet, a web page will displayed on the user's computer (fig. 14), and then the user's operation is similar to the operation on the main PLC controller's screen.

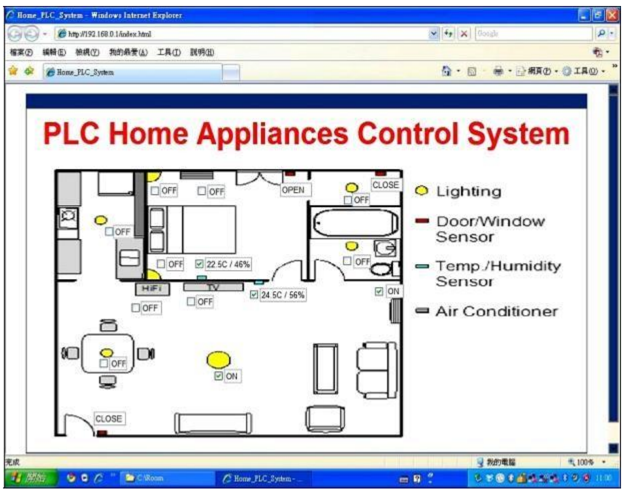

Fig. 14 PLC home appliances control via Internet browser

Figure 15 shows an experiment to switch the conventional electrical fan on or off by a PLC device controller on the home network.

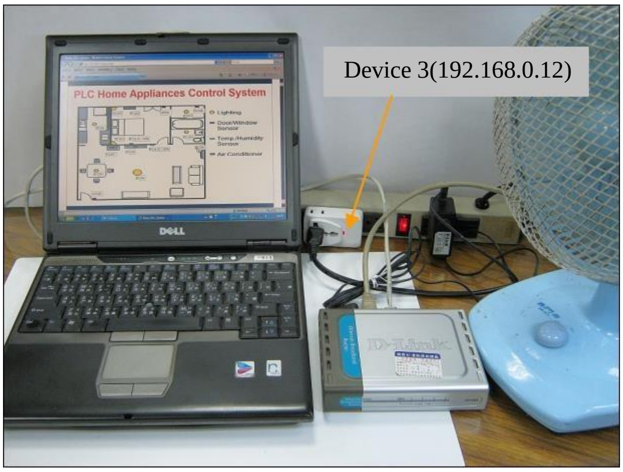

Fig. 15 Electrical fan control

V. CONCLUSIONS AND FUTURE WORKS

This work is to utilize the home electrical system for networking, the implementation of a home appliances control system based on the PLC technology has been successfully deployed. Authorized manager can access the main PLC controller to control the selected home electrical appliance or monitoring sensor's data locally or from the Internet.

The user's interface is quite convenient, via internet web browser from any platform to access this system. Data security also provided to protect the system from unauthorized access.

Although this system can process some simple tasks at this moment only, but it can be extended further for some additional functions, such as video camera and burglar alarm for enhance home security or automatic timer control for saving energy.

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