Smart House with Power Line Communication Network

Project Team: Kia Filsoof
Pranil Reddy
Yalda Hakki
Kevan Thompson
Michael Kubanski

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Supervisors: Dr. Andrew Rawicz
Mr. Steve Whitmore
School of Engineering Science
Simon Fraser University

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EXECUTIVE SUMMARY

In this day and age, communication is a very integral part of our society, and we rely more and more on it with new advances in technology every year. The Internet is a very popular medium for communication of ideas and information between people, but also for communication between devices, allowing for control of a device remotely. It is limited though as not everything can be hooked up directly to the Internet in a feasible and cost effective manner, for example, home appliances.

Control over home appliances, and more generally, control over a home or any other building remotely, has the potential to ease most peoples' hectic lives. Instead of having to physically get home and put on dinner after a long day of work, the alternative would be to connect to your home online, set the oven temperature and turn it on given that dinner was prepared ahead of time. What if you left for a vacation and forgot to turn off the lights? The ability to check on your house online would be very convenient.

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1. Introduction

With the addition of the Prometheus to your house, you now have the ability to control your appliances from anywhere in the world using the Internet. With Just a click of a mouse, you are now able to switch your house lights you forgot to turn off when leaving the house.

The objective of our project is to establish a working control system which will use power line communication to communicate and control home appliances. This project in particular, is aimed to be used within a house to control appliances such as light bulbs, coffee makers, and toasters. The major advantage of our product from similar devices on the market is that we are aiming to add extensive security to the already existing power modulation communication protocol. Moreover, many existing products have non-intuitive user interface, causing the user experience to be rather unpleasant. With the design of Prometheus, we are aiming to provide simple and innovative user interaction with the product.

After extensive research, power line communication has been successfully chosen as the method of communication for this control system for number of reasons. One of the major advantages with power line communication is that it utilizes the existing structure's electrical grid for communication purposes. This feature allows the overall cost of the system to drop by a noticeable amount.

Other options which were available to us for implementing the Prometheus device were to use either wireless or Ethernet for means of communication. As for the wireless method, even though it does not require any wiring, it would still add unnecessary complexity to the design of the system, causing the price to increase. Similarly, as for the Ethernet method, the cost would increase due to the cabling required.

2. Proposed Design Solution

Our proposed solution is to create a network of microcontrollers which will communicate over a Power Line Communication Network (PLCN). This solution will have a high performance microcontroller which will act as a master, to a series of low powered device microcontrollers. The master microcontroller will communicate to the device microcontrollers over a PLCN. This network will save costs by combining the power and communication lines into a single entity. In addition, it also consists of a very friendly user interface.

The user will select devices to be activated or deactivated by a password protected website which they will be able to access from any computer connected to the internet. This website will be stored on the master microcontroller, which will act as a web server. When a user has finished selecting devices the master microcontroller will then send the data to the appropriate device microcontroller which will then turn on or off the device.

For this project we attempt to control several simple devices such as lamps, or a coffee machine. If more time and funding were available, we would attempt to control more complex devices such as a smart oven, which would have configurable temperatures, and timing.

3. System Overview

The Prometheus general block diagram in Figure 1 shows the basic functionality of our product. The user can easily control a desired device remotely in the building from the Internet. The building master controller determines what device the user intends to control by the data received and sends control signals to the Power Line Communication Modem (PLCM). The control signals are processed by the PLCM and sent through the electrical grid. These signals are then recovered from the electrical grid by a PLCM located in the room and passed on to the corresponding device controller to control the required device.

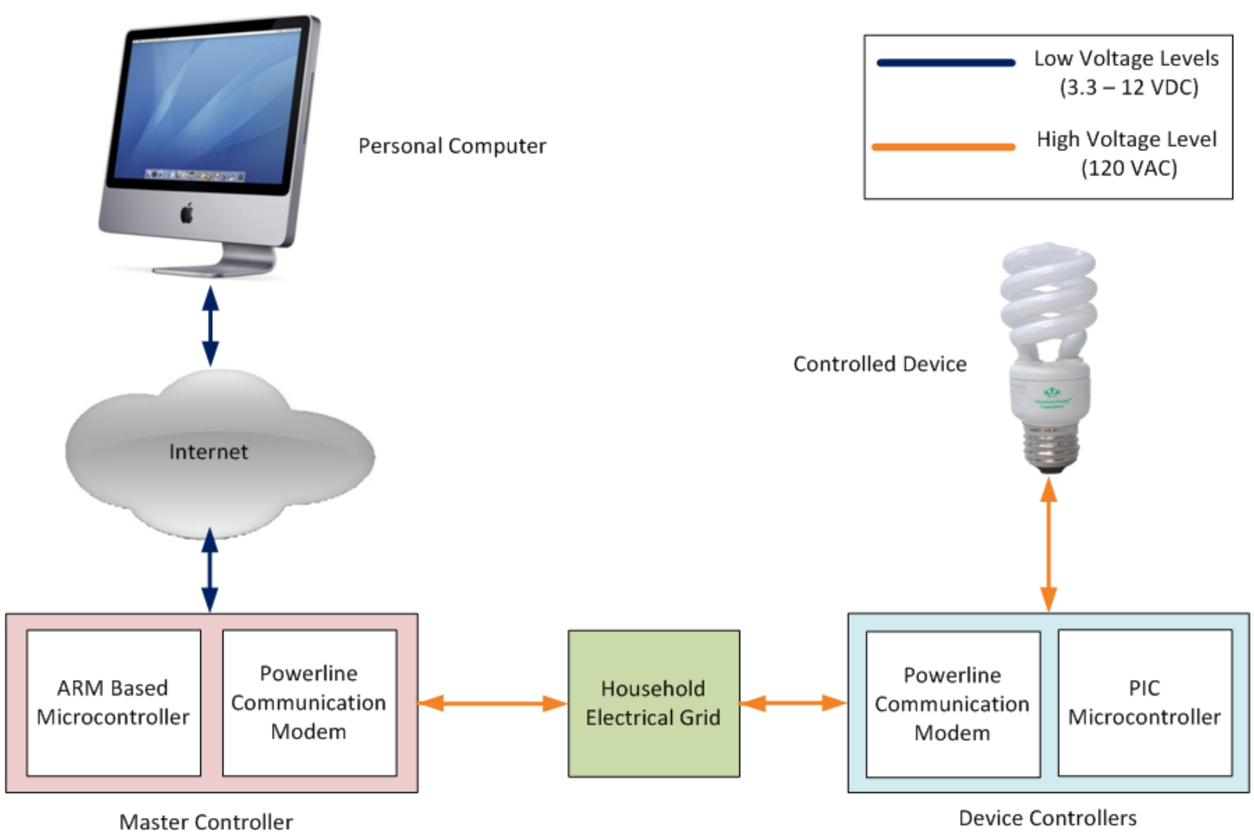

Figure 1: Conceptual Overview

3.1 Master Controller

The purpose of the master controller is to provide an interface between the user and the Prometheus system, as well as provide overall control of the system.

The master controller, illustrated in Figure 2, consists of a TS-7200 Single Board Computer (SBC) purchased from Technologic Systems.

Figure 2: TS-7200 SBC

The processor on the TS-7200 SBC is an ARM 9 processor which operates at 200MHz, and has 32MB of high speed DDR RAM. Debian Linux V2.6 is installed on a 2GB compact flash card, and is loaded on boot-up by manually interrupting the Redboot boot loader program. The user web interface will be provided by an Apache web server included in the Linux operating system. A terminal interface is provided by the COM1 serial port, and the COM2 serial port will be used for communication between the master controller and the device controller.

3.2 Power Line Communication Modem (PLCM)

The PLCM is responsible for transmitting/receiving the data signals over the power line. There will be a master PLCM which will be used by the master controller to communicate with the devices over the power line. There will also be an additional PLCM per each device's device controller which will be connected to the power line communication network.

The PLCM consists of four stages to account for data communication over the power line: modulator circuit, coupling circuit, decoupling/signal conditioning circuit, and demodulation circuit [1]. On the transmitting side, the RS232 data signal from the microcontroller is fed through the modulator circuit which will modulate this RS232 data into its corresponding FSK format. Then, the FSK modulated data signal is fed through the coupling circuit to be superimposed onto the AC power line signal. On the receiving side, the FSK modulated signal is extracted from the power line through the decoupling circuitry, and demodulated back into its RS232 data format via the demodulator circuit.

3.3 Device Controller

The device controller is required to communicate with the master controller and in regards to controlling the corresponding device connected to it. The device controller needs to be cheap, power efficient, and capable of handling communications with the master controller and controlling the required device. The device controller will need to receive and transmit RS232 data through the PLCMs and control a device using external circuitry connected to its I/O ports. The most cost efficient choice that can handle the processing requirements and the one we have chosen is a PIC microcontroller.

4. Use of IEEE Standards

IEEE Std 643™-2004 (Revision of IEEE Std 643-1980): Guide for Power-Line Carrier Applications [2]
We made use of this standard to aid us towards achieving data transmission over power line communication networks. This standard is provided with many useful guidelines regarding component selection, frequency selection, noise considerations, and channel losses which were very useful in regards to completion of our project.

IEEE Std 2001-2002: Software Engineering — Recommended Practice for the Internet — Web Site Engineering, Web Site Management, and Web Site Life Cycle [3]
We used this IEEE standard to follow industry related practises in design of our system's internet user web page.

5. Current State of the Project

The Prometheus system can currently control home or business electrical devices through a power line communications network on the building's power grid. A user can log onto a website hosted by the master controller, which will send control signals through the power grid to the corresponding device controller. The master controller and device controllers each consist of one power line communication modem (PLCM) which allows for their transmitting and receving of data over the power grid.

Currently the Master Controller uses a TS-7200 SBC with a Debian Linux operating system. The master controller can use an Apache webserver to create a dynamic CGI webpage that can communicate with a static process which runs the network. This static process, called master_controller, sends and recieves data from the CGI program and also controls the device controller network. Currently this network is only configured to operate with a maximum of two device controllers. Each device controller must connect to the network, and will then recieve data as the user uses the website. In order to communicate with the device controllers, the master controller uses an RS-232 interface in cominbation with GPIO. The GPIO is needed to turn on or off the transmitter on the PLCM.

As of to date, the PLCM is meeting majority of its most critical proof-of-concept requirements. The PLCM is capable of sending and receiving digital data reperesented in RS232 format over the power line at any desired baud rate. It can be connected to any microcontroller device and grant it communication over the power line. In other words, it is not dependent on any specific required microcontroller. The PLCM's interface to the power line consists of a high frequency coupling transformer with two filtering capacitors sitting on the hot and neutral lines of the power line. The purpose of these capacitors in conjunction with the transformer is to prevent the 60-Hz AC power signal from getting through to the low voltage secondary side of the PLCM. There are also two 250 mA fast blow fuses sitting onwards these capacitors to provide protection of our circuitry from any current surges on the power line.

When transmitting, the PLCM takes the RS232 control signals from a microcontroller, modulates them into their corresponding FSK format, and passes them on to an H-bridge circuitry which drives the coupling transformer with the required amount of current. Conversely, when receiving, the PLCM extracts the FSK formatted control signals from the coupling transformer, passes them on to a band-pass filter which will further filter out the 60-Hz power signal and the high frequency noise signals. After filtering is done, the control signals are passed on to a pulse-shaping circuitry and then a phase-locked loop which will demodulate the FSK signals into their corresponding RS232 format and output them to the receiving input of the microcontroller.

The device controller consists of a PIC mircocontroller connected to the PLCM through an RS232 line driver/reciever and an external device control circuitry used to control devices connected to 120 VAC power line. The device controller communicates with the master controller via RS232 packets which are passed to and from the PLCM and controls devices based on the control packets it recieves. The PIC drives an output pin high to turn a device on, and holds it low when the device is off. When the pin is driven high, it powers the optoisolator's LED, which drives the other side of isolator. This in turn provides just enough base current to switch a NPN power transistor on and switch a 12 VDC relay on. This closes the device circuit and allows the 120 VAC source to power the device.

6. Conclusion

In less than 4 months, through close collaboration between team members, we were able to carry out extensive research and design to develop a functional prototype incorporating the majority of functional specifications promised in a timely manner. Our product is currently capable of controlling the on/off state of any electrical equipment within a building from over the internet. Data communication over the power line has been successfully achieved, and consists of minimal error. The microcontrollers installed within our system provide extensive communication protocol within the system to account for any possible errors and addition or removal of any devices.

One of the critical improvements which can be made to our system towards having it ready for market would be to compactly enclose all current three units into one for every module. This enclosure will allow for more safety, easier installation and portability of our system by the user. The intended final enclosure is to be made of metal to allow for making use of grounding and heat dissipation purposes.

Another improvement to our overall system would be to reduce the overall power consumption of our system, leading to a less costly and more efficient device. All three of the master microcontroller, device controller, and the PLCM include circuitry which can be optimized more towards increasing the system's efficiency.

Lastly, our final product will need to be capable of controlling more complex devices. Currently, our system can only control the on/off state of the corresponding electrical devices. As for future improvements, we are aiming to interact further with the internal circuitry of more complex devices. For example, we could use our system to control the overall operation of an electrical oven such as controlling its temperature, the corresponding heating pads, its internal clock, and timer.

7. References

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