January 15, 2010

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Functional Specification for an Implementation of a Smart House using Power Line Communication

Dear Dr. Rawicz:

The attached document, *Functional Specification for an Implementation of a Smart House using Power Line Communication*, outlines the functional scope and requirements of our project for ENSC 440 (Capstone Engineering Science Project). We intend to research and implement a programmable power line modulation system, called Prometheus, which enables users to remotely check and control the status of the lights inside their buildings, through the structures existing power grid.

The purpose of this functional specification is to describe the high level functional requirements for both the proof-of-concept and final product. In addition, this document provides a set of standards and the system test plan and will be used by all members of the Nexus Technologies as a guideline for design, development and testing of the Prometheus system.

The Nexus team consists of five intellectual, highly motivated, and talented fourth-year engineering students: Kia Filsoof, Pranil Reddy, Yalda Hakki, Mike Kubanski and Kevan Thompson. If you have any questions or concerns about our proposal, please feel free to contact me by phone at (604)910-5747 or by e-mail at kjthomps@sfu.ca

Sincerely,

Kevan Thompson

Kevan Thompson
Chief Executive Officer
Nexus Technologies

Enclosure: *Functional Specification for a Smart House using Power Line Communication System*

NEXUS Technologies

Functional Specification for

Smart House with Power Line Communication Network

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EXECUTIVE SUMMARY

Many people frequently forget to turn all their house lights off before leaving their property, causing an unnecessary increase in their monthly electrical bills and waste of energy. Leaving an ordinary 100W light bulb on for 24 hours, costs up to 20¢ [1]. As small of an amount this may seem to you, imagine leaving a light on for one whole year; that adds up to cost $73.00. This is only the cost of leaving one light bulb on for one year, say you own a 10-story office building and there is the possibility of leaving 10 light bulbs on everyday for one year; the total cost of this would add up to $730.00. Nexus Technologies has come up with a low-priced and innovative product for home and office owners, allowing them to avoid such unwanted costs.

With the addition of the Prometheus home control system to your house, you will now have the ability to check and control the status of all the house lights located in your building by just logging into an internet website. Imagine how convenient that would be. You can now rush out of your house in the morning without worrying about leaving any house lights on, since Prometheus will provide you with easy control over your house lights via an internet website

Prometheus will be designed as a power line communication modem, meaning it will use the already existing power line wires within the property to communicate with the lights. This allows the price of this product to drop by a great amount as no wiring and very little labour will be required for installing this system in your building.

Many existing modern power line communication modems have non-intuitive user interface, causing the user experience to be rather unpleasant. Furthermore, the security protocols provided by these models are rather weak and prone to malicious attacks. Our product is aimed to provide extensive multi-layer security protocol to account for any possible hacking which may intend to occur. In addition, we will be strongly focusing on designing a simple and innovative product as whole to ensure a satisfactory and enjoyable experience for all users.

This project will consists of the research, design, implementation, and testing of a prototype system over a 4 month period. The scheduled completion of this project is set for April 20, 2010. The first half of this project will consist of designing and documenting the proposed project, while the second half of the project will focus on the implementation and testing of the prototype. The projected cost of the prototype system is approximately $300.00. The intended retail price of the Prometheus is to be approximately $500.00.

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Glossary

BER: Bit Error Rate

CEO: Chief Executive Officer

CSA: Canadian Standards Association

FCC: Federal Communications Commission

FSK: Frequency Shift Keying

MTBF: Mean Time Between Failure

PLCM: Power Line Communication Modem

PSU: Power Supply Unit

1. INTRODUCTION

The Prometheus system from Nexus Technologies will provide users with a practical low cost implementation of a smart home. Our smart home design will allow users to control the lights of their house from either a local computer, or any computer connected to the internet. The building 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 control signals are then recovered from the electrical grid by another PLCM located near the corresponding light that is to be controlled.

The scope, electrical, mechanical, safety and environmental system requirements will be described in this report. Moreover, our intended testing plan of the Prometheus system indicating the approach at which this product will be tested for its specified requirements will also be discussed.

1.1 Scope

This document illustrates the functional requirements that are intended to be met by the Prometheus system. These requirements fully describe the functionalities of the proof-of-concept system and to some extent explain that of the final production system. These requirements will be a backbone for the Prometheus system design and a source that will be referred to during the implementation of the product as a guideline by all members of the Nexus Technologies.

1.2 Intended Audience

All members of the Nexus Technologies will refer to this document during various phases of the design, implementation, and test of the product. The CEO will refer to this document in order to evaluate the progress of the project during the development stage. All members will also refer to the specified requirements in this document as their overall design objectives and as a measure of functional similarity between the final product and the functional specifications stated in this document.

1.3 Classification

To differentiate between different categories of functional requirements, the following convention will be utilized in this document.

[Rn-x] specifies a functional requirement with **n** indicating the number of the functional requirement, and **x** specifying the priority of the functional requirement. The following specifies the values of **x**:

I	Implies that the requirement merely applies to the proof-of-concept system.
II	Implies that the requirement applies to both the proof-of-concept system and the final production system
III	Implies that the requirement only applies to the final production system.

2. System Requirements

2.1. System Overview

Figure 1 illustrates the functionality of the Prometheus system. A specific desired light can be remotely accessed and controlled by the system. The user is only required to access the website that is hosted on the master controller in order to check or control the status of lights in his/her house. The master controller determines which light the user intends to control by the received data. The controller, then, sends control signals to the PLCM which processes the control signals and sends them through the electrical grid. Next, the control signals are recovered from the electrical grid by another PLCM and passed on to the corresponding device controller, which will then switch on/off the corresponding light.

System requirements are divided into 4 categories, namely, general requirements, master controller requirements, PLCM requirements, and device controller requirements.

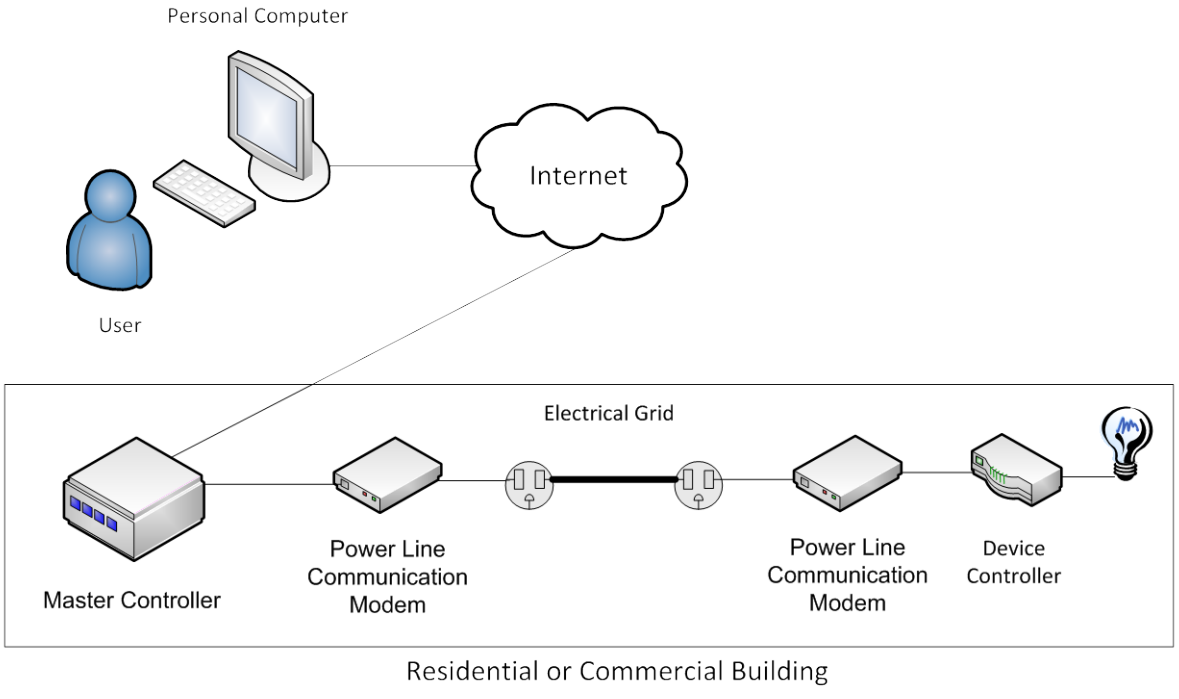

Figure 1: Conceptual overall system overview

2.2. General Requirements

[R1-III] The system's retail price shall stay under $500.00.

[R2-II] The user shall be able to use the Prometheus from the internet.

[R3-II] The user shall be able to check or change the status of the lights located within the building.

[R4-II] The communication protocol of the system shall have extensive security added to it to avoid any hacking of the system.

[R5-II] The user interface of the system shall be simple and innovative to ensure a smooth experience for the user.

[R6-II] The system shall be able to operate within typical room temperatures (15°C–25°C) [1] and humidity of 50% [1].

[R7-II] The system shall only be used indoors.

2.3 Master Controller Requirements

The Master controller undertakes the following general responsibilities:

- Communicates with the user through the personal internet website.
- Communicates control signals with the device controller via the PLCM.
- Provides a networking algorithm for communication with the device controllers throughout the building.
- Keeps track of all device controllers within the building within an dynamic database

2.3.1 General Requirements

[R8-III] The Master controller shall have a low power idle state for standby modes.
[R9-III] The Master controller shall have plug and play compatibility for easy installation.
[R10-II] The Master controller shall connect to the internet via an Ethernet cable.
[R11-III] The Master controller shall have total cost of no more than $250.

2.3.2 Physical Requirements

[R12-III] The electronics shall be contained in a box of 9.7 cm x 11.5 cm.
[R13-III] The box shall be aesthetically pleasing to the eye.
[R14-III] The box shall be made of plastic, to avoid potential shorts and unwanted conduction.
[R15-III] The box shall be durable and resistant to cracks/breakage.

2.3.3 Electrical Requirements

[R16-II] The Master controller shall operate from a 5V/400mA PSU.
[R17-II] The PSU shall be compatible with a standard 120V 60Hz North American outlet.

2.3.4 Environmental Requirements

[R18-III] The Master controller shall function normally at sea level and at elevations up to 2000m.
[R19-III] The system shall be able to operate within typical room temperatures (15 ºC–25ºC) [1] and humidity of 50% [1].
[R20-II] The operation of the Master controller shall be silent with minimal noise.
[R21-III] The Master controller will produce minimal heat.
[R22-III] The Master controller will be for indoor use only.

2.3.5 Standards

[R23-III] The Master controller shall conform to CSA [3] standards for household electronics.
[R24-III] The Master controller shall conform to FCC [4][/CE [6] standards for household electronics.
[R25-III] The Master controller shall conform to RoHS [7] standards for household electronics.

2.3.6 Reliabilities and Durability

[R26-III] The Master controller shall be able to withstand day to day wear usage.
[R27-III] The Master controller shall only be serviced by trained technicians.
[R28-III] The MTBF (Mean Time Between Failures) of the Master controller shall be no less than 10,000 hours.

2.3.7 Safety Requirements

[R29-II] The Master controller shall be safe to operate around people with a very low risk level.
[R30-III] The Master controller shall not spontaneously combust or explode.
[R31-III] All electrical components shall be enclosed.
[R32-II] The user should be able to easily install and uninstall the Master controller in a safe manner.

2.3.8 Performance Requirements

[R33-II] The Master controller shall have a very fast response time, such that the user cannot perceive a delay between sending a command and it being executed
[R34-III] The Master controller shall be able to notify the user of an error/failure through a red error LED, as opposed to a green LED signifying power on and normal operation

2.4 Power Line Communication Modem Requirements

The PLCM undertakes the following general responsibilities:

- Processes RS-232 data from the microcontroller into its corresponding Frequency Shift Keying (FSK) modulated format to be coupled into the power line.
- Extracts the FSK signal from the power line by means of filtering the AC 60 Hz signals.
- Demodulates the received FSK signal back into its corresponding RS-232 format to be fed into the microcontroller for interpretation.

2.4.1 General Requirements

[R35-III] The PLCM shall provide clear visual indication of its current status such as receiving, transmitting, standby, and power.
[R36-II] The PLCM shall use the FSK method for means of modulating control signals.
[R37-II] Phase Locked Loops (PLL) will be used for means of demodulating the FSK signals.

2.4.2 Physical Requirements

[R38-III] The PLCM's physical size shall not exceed 7.0 cm X 10.5 cm.
[R39-III] The PLCM's enclosure shall be made of non-conductive material.
[R40-II] The PLCM's electrical wiring shall be neatly routed within the enclosure.
[R41-II] The PLCM's enclosure shall comprise of buttons for turning on/off or putting the system on standby.

2.4.3 Electrical Requirements

[R42-II] The PLCM's power supply shall provide ± 15 V, at a current rating of 500 mA.
[R43-II] The peak power consumption of the PLCM shall not exceed 7.5 W.
[R44-II] The power adapter shall be usable with a standard North American 110V/120V, 60 Hz AC outlets.
[R45-II] The attached cord for the power adaptor shall have length no less than 1.5 m.

2.4.4 Environmental Requirements

[R46-III] The PLCM shall go into low power state (standby mode), after 5 minutes of inactivity.
[R47-III] The system shall produce at most 10 dB noise levels during operation.
[R48-III] The system shall produce as small amount of heat as possible during operation.

2.4.5 Standards

[R49-III] The PLCM shall make use of the EIA RS-232-C [8] standard.
[R50-III] The PLCM will comply with CSA [4], FCC [5], and CE [6] standards for house hold electronics.
[R51-III] The PLCM will comply with Energy Star's product efficiency standards [9]."

2.4.6 Reliabilities and Durability

[R52-III] All circuit components shall be modularized allowing for easy repairing of the device.

[R53-III] The enclosure shall be capable of proper dissipation of excess heat generated by the device under heavy operating conditions

[R54-III] The PLCM shall not be upgradeable or serviceable by the end user. Only qualified technicians shall service or upgrade the PLCM.

2.4.7 Safety Requirements

[R55-II] The system shall include fuses for ensuring no high current signals from the power line is present on the PLCM to avoid any fault conditions which may arise.

[R56-II] The system shall provide additional voltage segregation by the use of optical isolation between the high voltage sections and low voltage sections of the PLCM.

[R57-III] The PLCM shall notify the user of any errors or system faults which may occur during operation.

[R58-III] The PLCM enclosure shall be completely sealed to prevent unauthorized tampering of the device.

[R59-II] All materials within the PLCM will be non-flammable

[R60-III] The PLCM shall not have any sharp edges that may cause injury to the user.

2.4.8 Performance Requirements

[R61-II] The PLCM shall be able to operate at 9600 baud.

[R62-II] The PLCM's Bit Error Rate (BER) shall be kept to a minimum.

[R63-III] The PLCM shall have power consumption efficiency of at least 95%.

[R64-II] The PLCM shall filter out any noise present on the electrical grid to prevent any interference with the control signals.

[R65-III] The PLCM shall contain built in error correction.

2.5 Device Controller Requirements

The device controller in charge of the following responsibilities:

- Processing control signals from the PLCM.
- Controlling the device that it is attached by interpreting the received command.
- Transmits device status to the Master controller via the PLCM.

2.5.1 General Requirements

[R66-II] The device controller shall have a low power idle state for periods of standby.

[R67-II] The device controller shall have plug and play compatibility for easy installation.

2.5.2 Physical Requirements

[R68-III] The electronics shall be contained in a box of minimal size, determined by the size of the components.
[R69-III] The box shall be aesthetically pleasing to the eye.
[R70-III] The box shall be made of plastic, to avoid potential shorts and unwanted conduction.
[R71-III] The box shall be durable and resistant to cracks/breakage.

2.5.3 Electrical Requirements

[R72-II] The device controller shall operate from a 5V/400mA PSU.
[R73-II] The PSU shall be compatible with a standard 120V 60Hz North American outlet.
[R74-II] The device controller shall have protection implemented to guard against power surges.

2.5.4 Environmental Requirements

[R75-III] The device controller shall function normally at sea level and at elevations up to 2000m.
[R76-III] The system shall be able to operate within typical room temperatures (15 ºC–25ºC) [1] and humidity of 50% [1].
[R77-II] The operation of the device controller shall be mostly silent with minimal noise.
[R78-III] The device controller shall produce as little heat as possible.
[R79-III] The device controller will be for indoor use only.

2.5.5 Standards

[R80-III] The device controller shall conform to CSA [3] standards for household electronics.
[R81-III] The device controller shall conform to FCC [4]/CE [6] standards for household electronics.
[R82-III] The device controller shall conform to RoHS [7] standards for household electronics.

2.5.6 Reliabilities and Durability

[R83-III] The device controller shall be able to withstand day to day wear usage.
[R84-III] The device controller shall only be serviced by trained technicians.
[R85-III] The MTBF of the device controller shall be no less than 10,000 hours.

2.5.7 Safety Requirements

[R86-II] The device controller shall be safe to operate around people with a very low risk level.
[R87-III] The device controller shall not spontaneously combust or explode.
[R88-III] All electrical components shall be enclosed.
[R89-II] The user should be able to easily install and uninstall the device controller in a safe manner.

2.5.8 Performance Requirements

[R90-II] The device controller shall have a very fast response time, such that the user cannot perceive a delay between sending a command and it being executed.

[R91-III] The device controller shall not interfere with other electronic devices while operating.

[R92-II] The device controller shall be able to notify the user of an error/failure through a red error LED, as opposed to a green LED signifying power on and normal operation.

3. System Test Plan

In this section, the intended testing plan of the Prometheus system will be discussed. This document thus far has outlined the specific requirements which our system must qualify for. However, the approach and order of ensuring the qualification of these requirements will be discussed below. Since the project team has been divided separately for its hardware and software side, the system's hardware and software will mostly be tested separately during the initial design stages. However, wherever possible and applicable, both sides will be integrated and tested together as a whole, to avoid any costly failures. The hardware side of the project will include testing of the PLCM network, while the software side will include testing of the master and device controllers.

The PLCM will have to be tested for various functionalities. Its general operation will first be tested outside of the power line, and once approved; it will be set up for testing over the power line. The PLCM will be tested to see if it is capable of modulating the RS-232 data for transmission. Once verified, the modulated data will be fed back to the PLCM to check if it is capable of demodulating this signal back to the original RS-232 data. Upon verification of the PLCM's general functionality, we will next connect it to the power line and repeat the same testing procedures. A few items need to be considered when testing the PLCM over the power line, for example, coupling the message signal into the AC power line on the transmitting side and filtering out the AC power signal to extract the message signal on the receiving side.

As for verifying the functionality of the master and device controllers, they will both be tested on their ability of receiving and transmitting RS-232 data for means of communication with each other through the PLCM. The master controller is also responsible for storage and controlling of the internet website that the user will be logging in to control the status of their building lights. Therefore, the master controller will have to be tested to see if it communicates and responds to the website correctly during operation and outputs the correct RS-232 command to the PLCM. The device controller on the other hand, will also be responsible for receiving these control commands from the PLCM and responding to them by switching on/off the lights or reading their current status. Therefore, the device controller must be tested for this functionality accordingly.

Once both software and hardware side of the project have been verified for their parts separately, the system as a whole will be tested for its functionality. Figure 2 below provides a general action flow of our overall system from when the user requests to control a light and all the actions that will follow by the Prometheus to control the corresponding light. This flow diagram will be used as a test guide when verifying our overall system functionality.

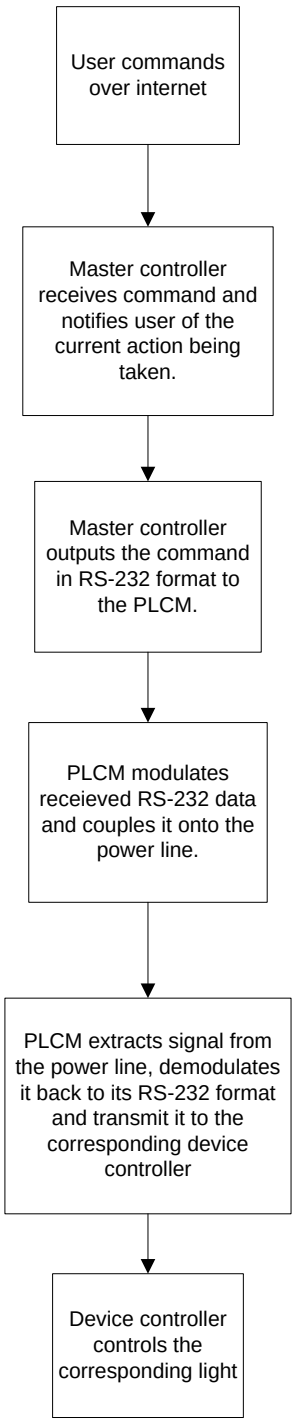

Figure 2: Overall general action flow of our system

The system's physical requirements will be tested once the whole system is assembled. All the specified dimensions will be accurately measured. As physical dimension is not the most critical requirement to meet for this particular project, any deviations that are within 10% of the specified requirement are

acceptable. The reliability, durability, and the environmental requirements of the system will be verified by ensuring all the components used in the system meet the specified requirements before purchasing. Also, the overall system as a whole will be put in the corresponding states and tested for its performance under each one. All the safety requirements will be met by overdesigning the system and testing certain fault condition to ensure that the built in safety circuitry reacts in to the corresponding fault condition in a predictable way. Also, the overall system as a whole will be put in the corresponding states and tested for its performance under each one. All the safety requirements will be met by overdesigning the system and considering all the safety components present during the entire development stage of the project.

4. CONCLUSION

The functional specifications describe the functionality in addition to various requirements, standards, and the test plan of the Prometheus system. Development of the proof-of-concept model is in progress. The proof of concept model is expected to meet the functional requirements outlined document in this and marked with either **I** or **II** by the target date of April 20, 2010.

This document will be referred to by the members of Nexus Technologies during the development stage of the product as a guideline. It will also be used to resolve any disagreements regarding the scope of project.

5. References

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