ZigBee-based Smart Environment for LED Light Control

2011 SBOE Idaho Incubation Fund Program

1 Executive Summary

Lighting is one of the most efficient methods to conserve energy. The Philips Research reports that switching from traditional lamps (incandescent and fluorescent lamps) to solid-state lamps using LEDs (LED lamps) has an immediate impact on energy use, CO_2 emissions and the environment and it also improves light quality [9]. Therefore, the Philips Research aggressively forecasts that the LED lamps market will grow on average by 45% per year and the size of the market will be $465 billion by 2015. This forecast from the Philips Research clearly indicates that LED lamps will be the future lighting devices for the next generation. Therefore, the PI is expecting that there will be a tremendous amount of market and business opportunities to bring a new level of elegance and reliability to LED illumination.

To exploit these tremendous business opportunities, the PI is proposing to improve the elegance and reliability of LED illumination via building a smart environment [1]. First, for the proposed smart environment, the PI will implement a low cost and low power *ad-hoc* wireless sensor network using *ZigBee* devices [12] . Second, the PI will develop a mobile application that enables people to access the proposed sensor network using smart phones. Finally, to showcase the new level of elegance to LED illumination, the PI will implement a smart application that brings dynamics of daylight inside the working environment by controlling LEDs on the sensor network. To demonstrate the power of the proposed smart environment, the PI placed a video clip of the prototypical implementation on the following *YouTube* link.

`http://www.youtube.com/watch?v=bs_ZPmuGkFQ`

[1] Smart environments are defined as a virtual world where different kinds of smart devices are continuously communicating to make humans' lives more comfortable.

2 Project Objective and Total Amount Requested

The most common features, which smart environments [3, 5] provide, are (1) remote control of devices and (2) information acquisition/dissemination from sensor networks. Despite the new range of capabilities with smart environments, enabling these two features is expensive and challenging due to a lack of preexisting network infrastructure and sensor networks [8]. The PI proposes to meet the challenge. **The objective of the proposal is to build a low-cost and low-power ZigBee-based smart environment to add a new level of elegance and control to LED illumination.** The successful implementation of the proposed smart environment will enable people to control the dynamics of daylight inside the closed area, such as library, student union building, etc., using smart phones. The requested budget for the project is $50,000, which covers the PI's two months summer salary, one student support, and tools and equipment purchase for the infrastructure. If the project is funded, the proposed smart environment for the LED light control will be installed on Boise State University.

3 Name of Idaho public institution

Boise State University

4 Name of faculty member directing project

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5 Description of how resource commitments reflect the priorities of the home institution

6 Evidence that the project will have a potential impact to the economy of Idaho

7 Establishes partnerships with the public or private sector contribute to new company creation

8 The Market Opportunity

The solid-state LED market made a great leap in second-half 2009, expanding dramatically from $7 billion in 2009 to $ 10.7 billion in 2010 (a growth rate unattainable by any other electronic product), according to the 'Global and China LED Industry Report 2009-2010' from market research firm Research In China [11]. Along with increasing LED brightness and falling prices, the penetration of LED lamps into general lighting is expected greatly. The general lighting market is of huge potential, with the market reaching $100 billion. Promisingly, the LED market is expected to reach $20.4 billion by 2012. The Philips Research even aggressively forecasts that the LED lamps market will grow on average by 45% per year and the size of the market will be $465 billion by 2015, which is about the same market size of incandescent and fluorescent lamps. These strong forecasts clearly indicates that LED lamps will be the future lighting devices for the next generation. Therefore, the PI is expecting that there will be a tremendous market and business opportunities to bring a new level of elegance and reliability to LED illumination. As one clear market evidence, to obtain the bigger LED lamps market share, Philips, GE, Harex, Illumitex, Sharp, and many other numerous LED companies are fiercely competing to

produce high *Color Rendering Index* (CRI) LEDs (100 being the maximum) with the lower price.

Surprisingly enough, except Philips Company and Redwood Systems, the PI has not observed any noticeable efforts to improve the elegance of LED illumination via sensor network based control. The discouraging news to the PI, however, is that the level of LED control research accomplished by these two companies is far beyond people's imagination. First, the Philips Company introduced the concept of *dynamic lighting* [2] and the company announced the LED solution that can emulate the dynamic character of light with its seamless changes in brightness and warmth.

Second, Redwood Systems [3] is officially launched its networked lighting management technology at GreenBeat 2010 Light-Fair. The company was founded in 2008 and based in Redwood City, CA. The company uses sensors, lighting and digital technologies to measure light levels, motion, occupancy, and temperature and can cut down the energy consumption of lighting in commercial buildings. Redwood Systems co-found and CEO Dave Leonard is a former Cisco executive, and the company raised $12 million from Battery Ventures and U.S. Venture Partners. Recently, the company also awarded $1 million from Department of Energy.

Nevertheless, there are two distinct differences between their sensor network LED control solutions and the PI's proposed ZigBee-based smart environment solution. First, since these two companies are targeting for commercial buildings, the installation and wiring cost for the sensor network are not suitable for an average household. On the contrary, the PI's proposed solution will exploit a low cost and low power wireless ad-hoc ZigBee sensor network. Therefore, the installation cost for the sensor network will be affordable for the average household. Second, unlike Philips Company and Redwood

[2]

- `http://www.dynamiclighting.philips.com/start_int.html`
- `http://www.youtube.com/watch?v=hwPxh2n0ClI&feature=related`

[3] `http://www.redwoodsystems.com/`

Systems, the PI's proposed solution allows people to access the sensor network using smart phones. Therefore, the PI believes, this will greatly enhance the people's experience in controlling the dynamics of daylight indoors.

9 The Technology

9.1 ZigBee Sensor Network

ZigBee [4, 12] is a specification for a suite of communication protocols using low power digital radios, which are based on IEEE 802.15.4 at the 2.4 GHz free frequency spectrum. The protocols are carefully crafted for low-rate decentralized *Wireless Personal Area Networks* (WPAN), which can still operate even when all other existing wired and wireless networks are down. In addition, ZigBee uses a low date rate, and therefore, it works with small data packet devices which need to operate for year(s) with a single battery charge. This *ad-hoc* nature of wireless networks and low cost and low energy requirements make ZigBee devices ideal for the proposed LED light control smart environment.

9.2 Mobile Application

Apple's iPhone [2] and various programmable phones based on the Android [1] have changed the way in which communication through much of the world. People start preferring smart phones over any other potable devices to access outside world. To correctly reflect the manner in which people currently interact with outside world, the proposed smart environment for LED lamps must be controlled using smart phones.

9.3 Prototypical LED Control System

The PI and one undergraduate student in the ECE department at Boise State University have developed a prototypical ZigBee based LED control system using Texas Instruments

eZ430-RF2480 demo boards [7], which are shown in Figure 1. To make each demo board serve as a communication point for the wireless ad-hoc ZigBee sensor network, the PI and the student reprogrammed TI eZ430-RF2480 boards using the IAR Embedded Workbench software tools for TI MSP430 [10]. This reprogrammed demo board is then connected to the Harex LED lamp [6] using GPIO pins, as being shown in Figures 2 and 3. By doing this way, the reprogrammed board serves as an actuator that controls the connected Harex LED lamp upon the command receipt from the wireless sensor network.

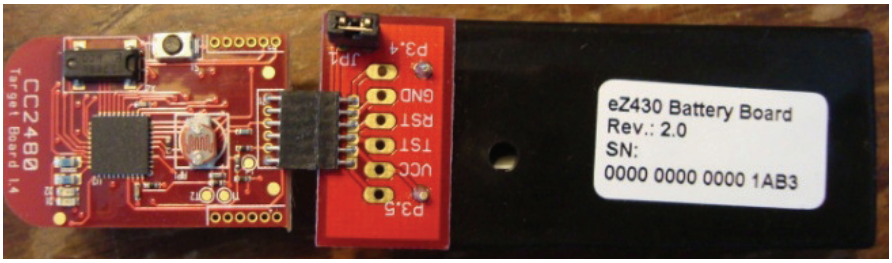

Figure 1: **Texas Instruments eZ430-RF2480**

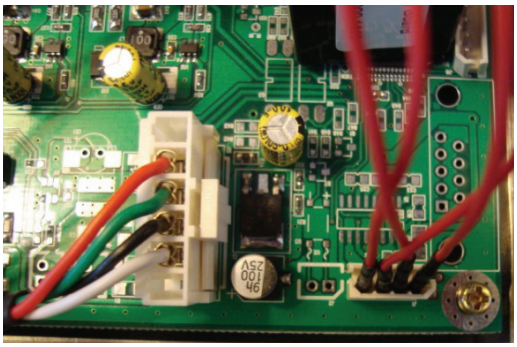

Figure 2: **Harex LED Light Device**

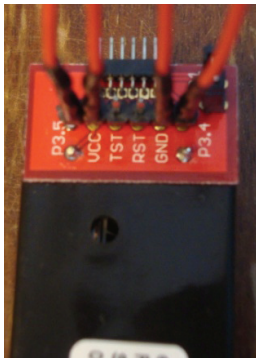

Figure 3: **Connect eZ430-RF2480 to Harex LED device using GPIO pins**

The PI have also implemented a preliminary version of an Android mobile application that enables people to remotely control three LED devices using a smart phone. In addition, the PI added the initial version of the dynamic lighting feature to the mobile application. To demonstrate the glimpse of the proposed smart environment, the PI placed a video clip of the prototypical implementation of the proposed environment on the fol-

lowing *YouTube* link.

`http://www.youtube.com/watch?v=bs_ZPmuGkFQ`

For the PI's prototypical ZigBee LED control ZigBee project, Harex provided LED devices and one Samsung Galaxy Android phone, Texas Instruments provided eZ430-RF2480 demo boards, and IAR system provided two one-year free license MSP 430 development tools.

9.4 Maturity of the System

For the prototypical LED control system, the PI uses only four ZigBee demo boards and one smart phone. Thus, to implement the proposed smart environment for LED control inside the working environment (library, student union building, and etc.), it is an absolute requirement for the PI to investigate (1) the stability and scalability of the ZigBee sensor network and (2) the wireless access quality using multiple smart phones. The following are some of many important questions that the PI needs to address while developing the proposed smart environment for LED control in a fail-safe manner.

1. what would be the optimal **density** of ZigBee sensor nodes for the proposed smart environment?

2. what would be the optimal **routing** topology and techniques to minimize the signal propagation delay and the lifetime of the battery powered ZigBee node for the proposed sensor network?

3. how the proposed smart environment guarantees **secured accesses** to the sensor network?

4. how the proposed smart environment handles **simultaneous accesses** to the sensor network form multiple smart phones?

5. how the proposed smart environment handles **conflicting commands** to the sensor network?

6. what would be the ideal dynamic algorithm to create the **dynamics of daylight** inside the working environment using LED lights?

The innovative responses to questions listed above will be the potential intellectual properties.

10 Commercialization Partners

1. Harex (Heart for Excellence) (http://www.harexled.com)

2. Micron Technology (http://www.micron.com)

11 Specific Project Plan and Detailed Use of Funds

12 Education and Outreach

For **Education**, the PI is preparing a Computer Science course on programming mobile devices for the Fall 2011. This course will be taught at both the graduate and undergraduate level using the Android [1] programming environment. If the project is funded, in this class students will work in teams to develop a variety of mobile applications to access the proposed smart environment.

Professor Ryu in the Department of Biology and Agricultural Engineering at University of Idaho has expressed a great interest in the proposed wireless ad-hoc ZigBee sensor network. For **Outreach**, the PI is actively exchanging ideas with Professor Ryu to apply the proposed sensor network to improve drought monitoring and forecasting efforts in rural and underserved area in Idaho. So far, we have contacted Ron Abramovich, USDA

NRCS Water Supply Specialist at Boise Idaho, and we are planing to prepare a collaborative proposal for 2011 USDA RFP.

13 Institutional and Other Sector Support

1. Harex
2. Texas Instruments
3. Micron Technology
4. IAR Systems

References

[1] Android. The android project. http://www.android.com.

[2] Apple. iphone by apple. http://www.apple.com/iphone.

[3] Sajal Das and Diane Cook. Designing and modeling smart environments. *International Symposium on a World of Wireless, Mobile and Multimedia*, 2006.

[4] Digi. Demystifying 802.15.4 and zigbee. http://www.digi.com/pdf/wp_zigbee.pdf.

[5] Smart environment. http://en.wikipedia.org/wiki/Smart_environment.

[6] HAREX. Natural led light. http://solist1.com/index.php?option=com_content&view=section&id=3&Itemid=67&e42217aba4a53afe0d50fae103e68be3=0e6fd6ea895fa46501f3208bcafb2772.

[7] Texas Instruments. ez430-rf2480. http://focus.ti.com/lit/ug/swru151a/swru151a.pdf.

[8] Wireless Ad Hoc Sensor Networks. http://www.antd.nist.gov/wahn_ssn.shtml.

[9] Philips Research. Green and lighting. http://www.usa.lighting.philips.com/lightcommunity/trends/green/green_and_lighting.wpd.

[10] IAR Systems. Iar embedded workbench for ti msp430. http://www.iar.com/website1/1.0.1.0/220/1/.

[11] Semiconductor Today. http://www.semiconductor-today.com/news_items/2010/JULY/RIC_060710.htm. July 2010.

[12] ZigBee. http://en.wikipedia.org/wiki/ZigBee.