Use of Wireless Sensor Networks for Fluorescent Lighting Control with Daylight Substitution

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ABSTRACT

This paper examines the use of Wireless Sensor Networks interfaced with Dimmable Fluorescent light fittings to allow for daylight substitution techniques to reduce energy usage in existing buildings. This creates a wire free dimmable fluorescent system for existing buildings with minimal disruption and cost.

1. INTRODUCTION

Dimmable fluorescent fittings, using modern electronic ballast dimmers[1] are widely fitted to new buildings, to allow for the accurate dimming and control of office lighting. Factoring in natural incident daylight, allows a reduction in the artificial light (daylight substitution), giving savings between 10% and 40%. The DALI[2] light control interface provides a two wire low voltage control bus to allow the addressing and control of individual light fittings. Unfortunately, for existing buildings, the requirements to install/cable in photo sensors and the lighting control bus, makes this approach impractical, unless a full renovation is in progress. In the US, some 6 Billion square meters of work space is economically unattractive for DALI[3] for this reason.

Wireless Sensor Networks can provide work plane light measurements, which can be forwarded to a standard building monitoring system, which can through the same wireless network control the dimmable ballast elements, allowing the retrofitting of existing installations without the need to re-cable and with minimal disruption.

2. LIGHTING REQUIREMENTS

The specifications and variations required for work plane lighting, for some sample areas are shown in Table 1, full specifications are in the CIBSE Lighting Guides[4]. Individual work plane light levels are typically read and forwarded to a facilities management system which can issue control signals to the lighting elements. Replacing the standard wired approach with a wireless interface is shown in Figure 1.

Table 1: Work Plane Light Requirements

Filing - Office Work	300 lux
General Office (writing, typing)	500 lux
Fine Painting (Industry)	750 lux
Precision Assembly (Industry)	1000 lux

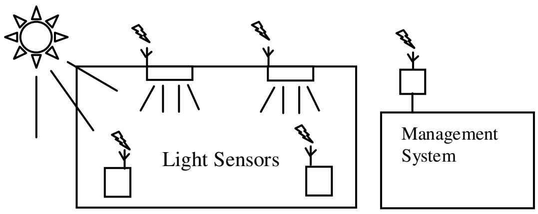

Figure 1: Wireless Daylight Substitution

3. WIRELESS SENSOR N/WS

The small unobtrusive size, achievable with sensor nodes and the ability to wirelessly network them makes them suitable to sensing light ambient levels in an office environment, and networking throughout the office for the communication of this information.

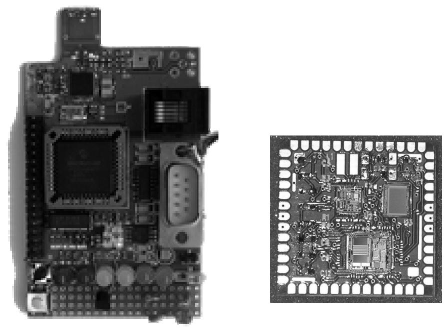

Figure 2: Sensor Test/Debug Platform, COB

3.1. CIT Sensor Architecture

The sensor node developed at CIT is shown in . It is controlled by a Microchip PIC16F877 microcontroller [5], uses a scalable clock from DC to 20MHz and a Nordic nRF903 868MHz FSK transceiver operating at up to 76.8kbit/s. Attached to it are a LDR and a thermistor.

4. DALI CONTROL INTERFACE AND SMART BALLASTS

DALI is a master/slave digital communication system that sends digital signals over a two wire bus network to provide full dimming and switching control of fluorescent lights down to the individual ballast level. The DALI forward communication protocol is 16 bits, containing both the device address and command, as shown in Figure 3. This allows control of up to 64 ballasts individually, which can be arranged as 16 groups or as an entire network. DALI ballast reference designs and kits are available from a number of manufacturers[6][7], all have a common element of a Microcontroller driving a ballast with a T5 or T8 fluorescent tube. The micro-controller interfaces with the DALI bus and interprets the on/off/dimming commands.

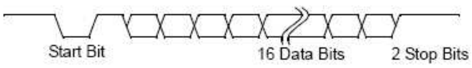

Figure 3: Dali Forward Frame

Using the micro-controller already in the DALI ballast and replacing the physical bus wiring with a radio transceiver provides an efficient extension of the ballast facilities, as shown in Figure 3. Parsing and interpretation of the DALI protocol on the PIC uses just under 2K of program memory and 71 bytes of data memory.[8]

The additional program memory available allows TDMA and hopping radio schemes back to the management system. Within a typical office environment, other fittings will be within range and the ambient light sensors will be within range of a fitment. Standard DALI allows a maximum of 64 ballasts, but extending the wireless packet format allows the additional addressing information, creating zones, using an extra byte for this purpose with 4 bits for zone identification and 4 bits for routing flags, can extend DALI to 1024 ballasts and use the wireless addressing for zone creation.

5. POTENTIAL SAVINGS

Globally lighting uses more than 2000 terawatt hours(TWh) per annum.[9] (Equivalent to 1000 power stations, producing 2.9 billion tonnes of $C0_2$ per annum.) The amount of power consumed in lighting varies widely from industrialised countries. e.g Netherlands - 5%, Israel - 19%, to developing countries, Tanzania - 86%. 64% of lighting electricity use is in the Service or Industrial Sector which are dominated by fluorescents.

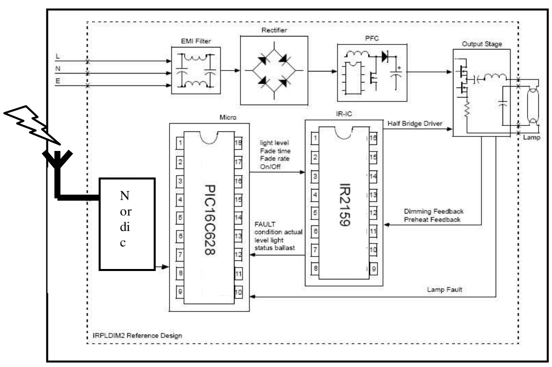

Figure 4: Block Diagram for Radio Interface DALI Dimming Ballast

If we take a typical office installation, using 1000 fittings each with two 58W tubes, used from 8am to 7pm, 2750 hours pa. With a conservative daylight substitution saving of 30% and a per Kwh cost of 10c, a savings of €9,570 per annum or €9.57 per fitting is achieved. The approx. 40% increase in tube lifespan saves another €200 on labour and €360 on materials using a wholesale tube cost of €0.90 in bulk quantities.

Other studies have shown payback in less than 3 years[10]. Installation costs of Daylight Substitution systems are typically dominated by labour costs, often in excess of 60% of the total cost. This also will be dramatically reduced with wireless networking.

6. CONCLUSION

This paper has proposed and examined a system to use wireless sensor networks to control dimmable lighting, using hopping networking strategies to transfer data to/from the photo sensors and fittings.

Integration of the wireless network elements with dimmable ballast controllers has been examined and a solution designed.

This wireless approach provides the ability to retro-fit existing lighting installations, giving significant cost savings with the corresponding environmental benefits.

7. REFERENCES

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