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INDOOR LIGHT ENERGY HARVESTING DEVICE

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ABSTRACT: In recent years, the design and development of energy-saving green buildings is an active area of research. Among various potential techniques, the utilization of a wireless sensor network (WSN) is widely used for intelligent building management applications. Typically, an intelligent building management system is used to monitor indoor environment parameters such as illumination, temperature, humidity and air quality. It has been reported that such an intelligent building monitor can save up to 20% of the energy usage, a considerable step toward the realization of smart building management. In conventional WSNs, the battery is used to energize these micro-scale sensors. However, frequent battery replacement poses big problem. In this paper, we construct of a WSN system for intelligent building environment monitoring in green high performance buildings powered through harvesting the indoor ambient light energy. A temperature sensor array was installed to demonstrate the feasibility of an infinite lifetime operation of a WSN system by harvesting the indoor light energy as the power source.

KEYWORDS: Energy Harvesting, Thermoelectric Generator, Wireless Sensor Network

I. INTRODUCTION

For the past decade, innovations in the design and construction of sustainable green buildings are receiving growing attention. Using renewable energy as alternative power supplies in smart buildings is now an old thing. A widely distributed sensor network can collect the building environment parameters, such as artificial lighting, temperature, air quality, humidity and transferring these parameters to a central control computer, which runs a certain algorithm or software to optimize the HVAC system operation and provide effective heating, cooling, lighting, and ventilating. In practice, even a small adjustment to the operation of HVAC systems could result in a significant reduction of energy consumption and operating costs. Emerging wireless sensor networks (WSN) provide an intelligent solution to control and management of the building environment by adjusting temperature, CO2 level, artificial lighting, and humidity to changing conditions. It has been reported that such an intelligent building monitoring and control system can result in energy saving, a substantial step toward the realization of smart building automation and management.

From the building maintenance perspective, without any battery replacement, these intelligent WSN systems are often required to operate for several years, because frequent battery replacements may lead to being expensive. To simplify installation, WSN systems are usually battery powered. However, a conventional battery has limited energy capacity and large volume compared with other system components, and finite recharging cycles. Thus, battery integration can result in a big limitation on the wide deployment of such applications for intelligent building management. As a result, a key challenge in these WSN systems is to efficiently provide the required power for achieving long-lived, maintenance-free operation.

Environmental energy harvesting is an attractive option to compensate for the power supply challenges in these systems. Ambient existing energy sources such as light, heat or vibration have the potential to achieve self-powered, perpetual system operation and eliminate the cost required for regular battery replacement. Among these options, light energy harvesting is the most practical solution. In addition, to decrease the cost associated with a frequent battery replacement, micro-scale light energy harvesting also provides significant environmental benefits. For example, every year millions of discharged electrochemical batteries result in a long-term threat and pollution to groundwater and soils. The use of energy generation techniques to successfully power wireless sensor nodes helps to reduce the number of batteries deposited into the environment.

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Systems that convert outdoor sunlight into electrical energy to support WSN systems have been prototyped, unlike the outdoor application, for indoor conditions, the overall light energy density is inherently limited. This together with low light energy conversion efficiency in an indoor environment makes indoor light energy harvesting very challenging. For indoor light energy harvesting applications, it is therefore important to optimize system design so an energy harvester can provide sufficient energy to the WSN in low illuminance level. In addition, many other system design issues require considerations, such as small form factor, output voltage level, capacity of the energy storage, cost efficiency and 'plug and play' ability. Furthermore, these factors are not isolated but are dynamically inter-related.

In this paper, the feasibility of indoor light energy harvesting to support the deployment of smart wireless sensor nodes for intelligent building environment monitoring is investigated. A WSN system for collecting environmental temperature values in the Department of Building Construction Management (BCM) of Purdue University. A cutting-edge small area (2.25 in × 2.25 in) photovoltaic cell was used for indoor ambient light energy conversion and the WSN system was tested in various indoor light conditions (i.e. different light intensities). Results have validated the feasibility of harnessing indoor light energy to power WSN systems for self-powered operation

II. LITERATURE REVIEW

In this paper, the researcher presented the architecture and implementation of a modular smart automation system for energy-efficient housing that was optimized for low-cost, the flexibility of system configuration, and interoperability with other technologies. The core of the proposed system consists of the Central Processor Unit (CPU), Wireless Sensor Network (WSN), Programmable Logic Controller (little PC), and Model Predictive Control algorithm of the building HVAC system (MPC). The loosely coupled system framework enables easy adaptation for various specific usage scenarios, both in adding the new hardware system components, and the additional software services. Linux-based CPU promotes an open system approach design which enables adding new functionality as a new system process that integrates with the rest of the system through the dedicated IPC messaging protocol. The WSN was optimized for energy-efficient smart home monitoring usage scenarios, and it provides low-cost multifunctional sensor nodes, with ultra-low power consumption and simple messaging protocol. Furthermore, improvements in reducing the overall system costs and in providing the extra features usually met in high-end industrial PLCs have been achieved by means of the custom-developed little PC. Finally, the MPC control algorithm plays a key role in a system that enables significant energy efficiency improvements[1]. In this literature, got to know about distributed sensor network can collect the building environment parameters, such as artificial lighting, temperature, air quality, humidity and so on. Then, these parameters are transmitted to a central control computer, which runs a certain algorithm or software to dynamically optimize the HVAC system operation with the help of the WSN system and provide efficient heating, cooling, lighting, and ventilating. However, in these WSN systems, battery is used to power up the micro-scale sensors. However, battery-powered WSN systems suffer from the difficulty of frequent battery replacement which leads to high labor cost, which impedes its practical use for building monitoring, control and management. In this paper, the authors investigated a temperature difference powered WSN system that harvests the environmental thermal gradients as the power supply[2]. This paper presents and evaluates the environmental factors, component choice, design concepts and main trade-offs in a PV panel-based energy harvesting WSN system design. The available light energy in the target deployment site has been carefully studied and the illuminance level and spectral power density in the target deployment area has been determined. Based on this, the PV cell bests suited for the indoor light energy harvesting has been chosen[3]. This paper has introduced an aerodynamic flutter-based energy conversion device driven by the airflow in an indoor ventilation duct. A power management circuit with a super capacitor, a charge pump and a DC–DC converter is integrated to store the harvested energy and to support applications requiring power at the mW-level[4]. In this paper we present a complete design flow and some design considerations. A power management circuit prototype is designed and tested with wireless temperature and humidity sensor. The measured results show that the proposed system can successfully drive the sensor node, which indicates the feasibility of micro-scale indoor light energy harvesting for wireless sensor network applications under extremely low light energy input environments[5]. This literature discussed the issues about energy harvesting using indoor light. Light energy was characterized, as well as the electrical model for PV cells. From different technologies, amorphous silicon showed to have a better result to harvest indoor light energy. Light power and irradiance measurements were performed in order to check the real energy availability in an indoor scenario[6]. This paper systematically analyzed the various components, design choices, and tradeoffs involved in the design of a solar energy harvesting module and their impact on its efficiency and illustrated how harvesting aware power management improves energy usage compared to battery aware approaches[7]. In this paper we have investigated a challenging application scenario for WSNs: Realization of energy efficient buildings. The reference scenario of the eDIANA project is reproduced and studied through simulation analysis and a real test-bed based on IEEE 802.15.4 Freescale devices. The network performance have been studied in terms of packet error rate, average delay and energy consumption. Simulation results verified by experimental activity show that the application requirements are satisfied and demonstrate the applicability of IEEE 802.l5.4/ZigBee mesh topology to the eDIANA scenario[8].

III. METHODOLOGY

The use of a WSN can be used as a cost-effective platform for intelligent environment monitoring and HVAC operational adjustment for future energy-efficient green buildings. Till date, there are several WSN systems presented in literature for intelligent building environment sensing and monitoring. However, in these WSN systems, the battery is used to power the micro-scale sensors. The operation of each sensor node is depending on the remaining energy status of its associated battery. Due to the small size constraints of the sensor node, battery size is very limited and can only last several months. As a result, the resultant labor cost for frequent battery replacement is prohibitively expensive. The focus of this paper is to investigate the feasibility of harvesting environmental light energy as the power source for each sensor node, thus, eliminating the requirement of frequent battery replacement. The wireless sensor node utilized in this demonstration is based on components developed from Texas Instruments. Instead of installing battery packs within each sensor node, a small piece of high-efficiency solar panel is used as the energy transducer.

The device consists of multiple compact wireless sensor nodes, one wireless access point, and a central control computer. Through a wireless link, these temperature values were transmitted to the access point and then displayed in the central control computer for observation and analysis. The entire system is illustrated in Figure 1.

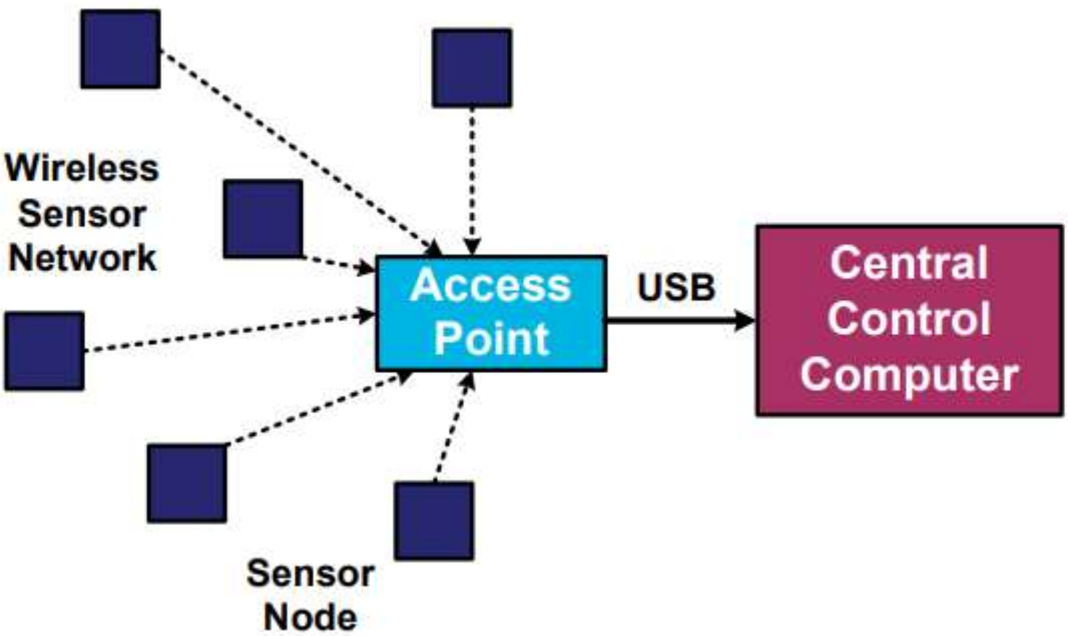

Figure 1: WSN System Architecture for Building Environment Monitoring

For sensing purposes, we used eZ430-RF2500-SEH sensor nodes from Texas Instruments, as shown in Figure 2. This board is equipped with low power devices such as a MSP430F2274 microcontroller and a CC2500 2.4 GHz wireless transceiver. The entire board is also integrated with a high-efficiency solar panel, which converts ambient light energy into electrical energy that provides harvested power to sustain the whole sensor operation. The product datasheet reports that the minimum operating light intensity is as low as 200Lux, which is above the common light intensities found in most offices. Each node module may contain plurality sensors for measuring parameters such as temperature, humidity, or illumination.

The access point consists of a wireless transceiver (CC2500 chip), a MSP430F2274 microcontroller, and a USB interface. The function of an access point is to receive the data transmitted from each sensor node and pass these data to the central control computer through a USB connection. The entire hardware structure for an access point.

Texas Instruments provides computer-based software that allows interaction with sensor nodes for effective data retrieval and analysis, as well as reprogramming the network configuration. The status of each deployed sensor node is able to be displayed in a graphical representation style. In addition, this interface also supports the storage of the received data in a text format. This option is very useful for searching for a specific node's status and data analysis afterwards.

IV. RESULT

We set up the battery-less WSN system for environmental temperature monitoring. A wireless sensor node is attached on the surface of a wall. Since there is no window for the outdoor light to enter hence the ceiling mounted light in the room act as an ambient energy source for this node. The central control computer utilized as well as the USB access point module connected to central control computer using USB. The measured temperature value of each sensor node is displayed on the computer screen for easy observation. Each yellow icon depicted on the computer screen indicates a sensor node that is communicating with the access point which is symbolized by the red icon in the center. Data samples were continuously collected, stored, and updated in the control computer for three days. To understand the impact of different light levels, some sensor nodes were moved to dim places where the light conditions were much lower. It was observed from the control computer that their corresponding yellow icons disappeared after a few minutes. This phenomenon implied that these sensor nodes stopped signal transmission after running out of their remaining power. On rare occasions during the three-day demonstration, we observed that one or two sensor nodes were not able to connect with the access point main reason behind this is a particular sensor node was temporarily shadowed by people walking around. When the individuals walked out, the sensor node was able to reconnect after a few minutes of delay. We also get to know that the maximum reliable communication distance from a sensor node to the access point was 16 meters. The presence of walls or doors between nodes and the access point did not appear to significantly degrade wireless transmission.

V. CONCLUSION

Distributed use of a wireless sensor network is a promising solution to optimizing control and management of the operation of a building's HVAC systems. The main challenge in existing WSN systems is to efficiently provide energy to each sensor. Therefore, we propose the harvest of environmental light energy as the power source for individual sensor nodes. To verify the potential of the proposed idea, a demonstration at Purdue University was conducted. The results substantiate the concept of harvesting ambient light energy through a tiny solar cell for this purpose. More extensive field testing is suggested to verify the feasibility of a WSN system to achieve long-lived, maintenance-free operation.

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