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WEB-BASED WIRELESS SENSOR SYSTEM FOR REMOTE AIR ENVIRONMENT MONITORING IN A COMMERCIAL WINERY

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SUMMARY

A fully-automated, low-energy sensor system was developed to take periodic measurements of environmental parameters in industrial settings to monitor the evolution of microbiota in wineries. The system design minimizes maintenance of sensor nodes and allows for convenient access to the data at remote locations. The wireless sensor nodes are battery-powered and operate unattended for several months. This was accomplished by placing electronic subsystems in low-energy consuming states and only activating specific subsystems when needed. Data is collected periodically from the sensor nodes and transmitted wirelessly to a receiver where it is formatted and uploaded to the internet. The operation of the sensor system is illustrated by presenting air monitoring data collected in a commercial winery during the first four days of harvest.

INTRODUCTION

The ability to monitor environmental parameters in a building at low cost is made possible by technological advances in the consumer electronics sector where the use of wireless technology and low-cost sensors has become ubiquitous. Furthermore, there is an increasing interest in internet of things, where everyday objects have network connectivity allowing them to send and receive data and enable data collection at remote locations. For our research on microbiota populations within wineries, we take advantage of commercial sensors to monitor multiple parameters in real-time from a remote location. Our focus is on wineries where an important consideration is to deploy a sensor system that is unobtrusive to ongoing operations. Sensor nodes are often needed in locations where wired connections are too restrictive. Such untethered sensor nodes also simplify the installation as multiple sensor nodes can be deployed fast with minimal interruption to ongoing activities in the winery.

METHODOLOGIES

A wireless point to multipoint network topology using IEEE 802.15.4 communication protocol was implemented. This achieves low cost, low-energy, two-way wireless communication (Callaway et al., 2002) in a static sensor network that uses small data packets that are transmitted infrequently (Willig et al., 2005). The data from each node is sent to a single, centrally located receiver (ConnectPort X2) that places the information onto the cloud. The ConnectPort is wired to the Ethernet and electrical power is wired using Power over Ethernet technology.

Multiple sensors were integrated to create sensor nodes to sample several environmental parameters every 15 minutes at multiple sites in a winery. Two types of sensor nodes were developed. The main node accommodates sensors demanding large powers and has a wired power connection. The main node periodically collects carbon dioxide, relative humidity, temperature, and volatile organic compounds (VOCs) data and has an option to monitor dust particle concentration. The constant power draw requirements of the VOC sensor (iAQ-2000) and particle concentration sensor (Dylos DC1700) demand a wired electrical connection. A single sensor (COZIR, GC-0011) is used to detect temperature, carbon dioxide, and relative humidity. The second node is an untethered satellite sensor node that only uses sensors with low average power requirements and is designed to operate from a battery for several months. The satellite sensor node only contains a COZIR which requires low power and short turn on time (<3.0 seconds). The satellite nodes are located in various hard to reach locations throughout the facility (e.g., red and white barrel rooms, wine transfer areas, labs, and outside air).

The necessity for battery-powered satellite sensor nodes capable of operating over long intervals without battery replacement makes attention to energy conservation details very important. First, a rechargeable, high energy density battery is used (single lithium ion battery, Panasonic, NCR18650A, typical capacity 3.1 Ah, nominal voltage 3.6 V). Second, the energy consumption is managed to maximize the use of a single battery charge by providing power to specific electronic systems only when needed and otherwise keeping the electronic system in the lowest powered state possible. In our current implementation we achieve an estimated 48 months before the battery is depleted.

The energy consumption on the satellite node is categorized into five subsystems: the microcontroller, the real-time clock, the regulators, the wireless module, and the sensors. The microcontroller is the programmable state machine that reads information from the sensors at specified times, communicates with the wireless module, and programs the clock. The microcontroller transitions back and forth between collecting and sending data, and waiting for the next transmission interval. The waiting period dominates the overall time. Limiting energy consumption during the wait time is most critical in lowering the average energy use. The clock is a timer programmable by the microcontroller. Its main role in this application is to keep track of time when subsystems are switched off and wake them up when high energy consuming tasks need to be accomplished. The satellite nodes use the Programmable System on Chip (PSoC) 5 microcontroller (CY8C5467AXI-LP108). PSoC5 offers a sleep mode that consumes current as low as 2 μA, while switching off most microcontroller functions, but keeps a counter internal to the microcontroller active to serve as the clock. Voltage regulators connected to the lithium-ion battery provide a fixed voltage to the electronic components independent of the current usage. In the satellite node we used two 3.3V regulators. The first (NCP583SQ33T1G, 1 μA quiescent current and 0.1 μA shutdown current) is connected to the COZIR sensor and can be placed in shutdown mode. The other regulator (NCP585DSN33T1G, 4.5 μA quiescent current) serves the other electronic subsystems and the quiescent current is its lowest current mode because it is never shut down. During the waiting period between data transmissions, the XBee radio transmission module (Pro S1, XBP24-AUI-001, 2.4GHz, data rate 115.2 Kbps) and COZIR energy consumption must be limited as well. XBee Pro modules were selected for increased range required for building environments that will contain obstacles that attenuate the radio frequency signal. The choice comes at the expense of higher current consumption when transmitting. The XBee module has three current consumption states: hibernate (<10 μA), receive (55 mA), and transmit (250 mA). The COZIR sensor is shut down when measurements are not being taken by using the enable input on its dedicated voltage regulator. This gives the COZIR two current consumption states: sleep (0.1 μA) and active (~1.5mA).

Average energy consumption can be greatly reduced by developing code strategies that limit the need for retransmissions when errors occur. Error checking code to sense when an error occurs was implemented by sending the number of bytes that should be received and then the measurement data. Upon the detection of an error, an automatic repeat request occurs. In the event of consecutive data transmissions not being received correctly, a retry delay is implemented on the PSoC to prevent the XBee from draining the battery with constant retransmissions. Upon receiving the data correctly, the Python script formats the data into tab-delimited form and writes the entry into a data file that is accessible remotely (Etherios Device Cloud, Digi International). The data can then be easily graphed with another application, granting real-time models of several environmental conditions throughout a building. This simple error checking approach resulted in a high degree of success in three fully operational wineries during the 2014 harvest season. More advanced error correction techniques can also be implemented when needed (e.g. such as described in Li et al., 2010, Peng et al., 2013, Piyare et al., 2013).

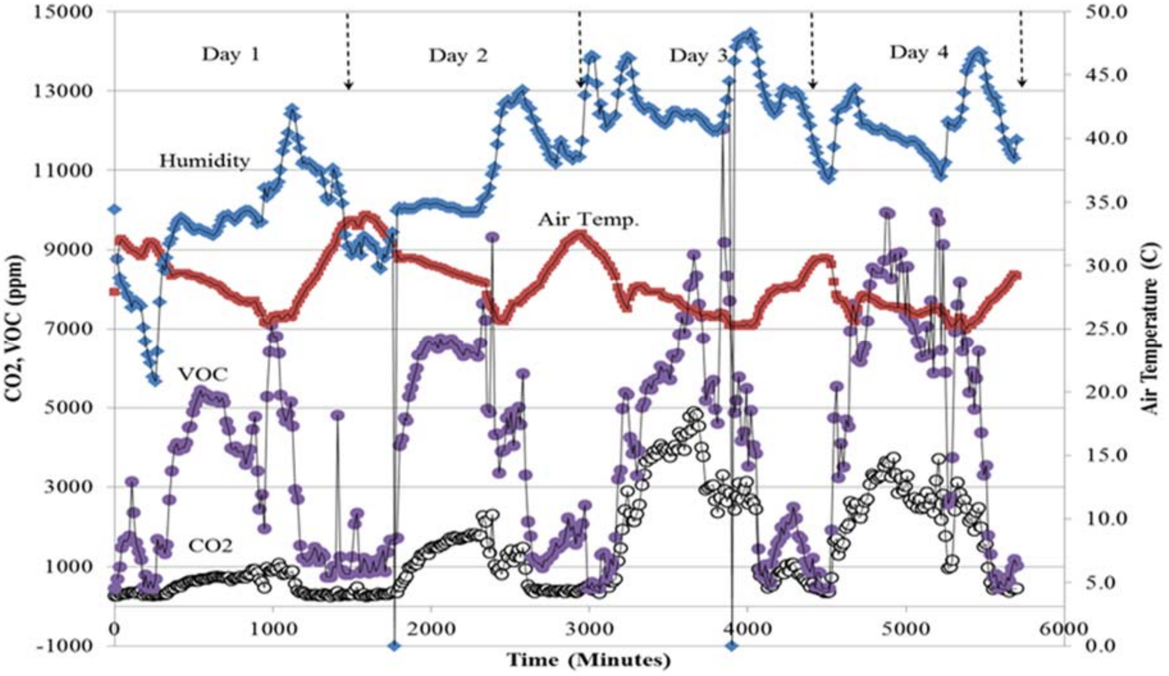

Figure 1. Ambient temperature, humidity, carbon dioxide and volatile organic compounds raw data collected in the fermentation hall of a commercial winery during the first 4 days of harvest.

RESULTS AND DISCUSSION

The data presented in Figure 1 shows the temperature, humidity, carbon dioxide, and VOCs data monitored with the system during the first four days of harvest at a winery 75 miles away. The daily patterns in temperature and humidity are due to the fact that there are doors open during the working period that are then closed at the end of the work day. This results in air cooling within the building and increasing humidity as wet surfaces from cleaning begin to dry out. The concentrations of carbon dioxide and VOCs both rise when the building is closed and decline the next morning when the doors are opened. The increasing peak height of these parameters is due to the increasing juice volume that is actively fermenting in the first days of the harvest. One important observation from this data was the realization that in this winery the carbon dioxide level rose to near the permissible exposure limit of 5000 ppm at about two and half days into the experiment even though it is equipped with carbon dioxide sensors that control exhaust fans in this fermentation room.

CONCLUSIONS

The system we developed demonstrates the feasibility of measuring environmental parameters in a winery during harvest and transmitting the data from a remote location to the internet. The strategy used to decrease the average power consumption allows the battery-powered sensor node to operate unattended for 48 months. The resulting data gives insight into indoor air parameters enabling decision-making based on real-time physical evidence. For example, using the graphed data, the ventilation system of a winery can be analysed and modified to ensure desired carbon dioxide and VOC levels are sustained.

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