

Demo Abstract: Powering Indoor Sensing with Airflows – A Trinity of Energy Harvesting, Synchronous Duty-Cycling, and Sensing*

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ABSTRACT

For indoor *Wireless Sensor Networks* (WSNs), as the conventional energy harvesting (e.g., solar) ceases to work in an indoor environment, the limited lifetime is still a threaten for practical deployment. We report in this demo a self-sustaining indoor sensing system. First of all, given the pervasive operation of *heating, ventilation and air conditioning* (HVAC) systems indoors, our system harvests energy from airflow introduced by the HVAC systems to power each sensor node. Secondly, as the harvested power is tiny (only of hundreds of μW) such that the exiting sensor products cannot be afforded due to their high energy consumption, we exploit the feature of our harvester to sense the airflow speed in an energy-free manner, which can pay back the environment by enhancing the awareness of the indoor microclimate. We also present two complementary algorithms to synchronize the duty-cycles of the sensor nodes to adapt to the energy harvesting. To our knowledge, this is the first indoor wireless sensing system that encapsulates energy harvesting, network operating, and sensing all together.

Categories and Subject Descriptors

C.2.2 [Computer Communication Networks]: Network Protocols; C.2.4 [Computer Communication Networks]: Distributed Systems]

General Terms

Design, Algorithms, Performance, Experiments

Keywords

Indoor energy harvesting, duty-cycle, synchronization

1. INTRODUCTION

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Recent years have witnessed the increasing applications of WSNs in indoor environmental monitoring [2] Unfortunately, one of the most challenging problems is the conflict between limited lifetime of the WSNs and their purpose for a long-term monitoring [1], especially considering the commonly used energy sources (e.g., solar energy) may not be available in an indoor environment.

One typical indoor application of WSNs is *microclimate control* [3,4]. The aim is to adapt the output of HVAC systems to population density, which may save energy while improving the comfort level of occupants. To this end, a sensing system is required to “sit” beside the outlets and measure the speed of airflow, whose output is in turn fed to the control system for precise actuation. Obviously, the sensor nodes of this system (close to the outlets) are often far from power grid, and it is not affordable to frequently maintain them (e.g., changing batteries) given the large number of outlets. Therefore, we dedicate a prototype of energy harvesting system in this demo to such applications.

In this demo, we present Trinity as a self-sustaining sensing system. We design a special type of energy harvester for drawing energy from the vibration of piezoelectric materials driven by airflows from HVAC outlets. Besides, we produce a general-purpose power management module to efficiently utilize piezoelectricity from the harvester. Furthermore, since the energy harvested from HVAC system is tiny (only of hundreds of μW) such that the off-the-shelf airflow sensors cannot be employed due to their high demand in energy, we innovate in proposing an energy-free sensor for detecting the airflow speed, using the physical features of our energy harvester. Additionally, considering such a limited energy supply, the sensor nodes have to operate under an extremely low and synchronous duty-cycle. We thus present two complementary synchronization strategies with very low energy consumption to serve this goal. The first one calibrates the native clock of a sensor node using the periodic output of our harvester when there is no data traffic, and the other one relies on the data traffic to perform constant synchronization among the nodes. We finally build Trinity as a prototype of a self-sustaining indoor airflow sensing system.

2. TRINITY SENSING SYSTEM

We first sketch the schematic of our Trinity system in Figure 1. The harvester is simply a frame with piezoelectric sheets (bimorph and unimorph) attached in the middle. We use a MicaZ Mote running TinyOS 2.1 as the sensor node platform, but *Trinity can be readily adapted to all oth-*

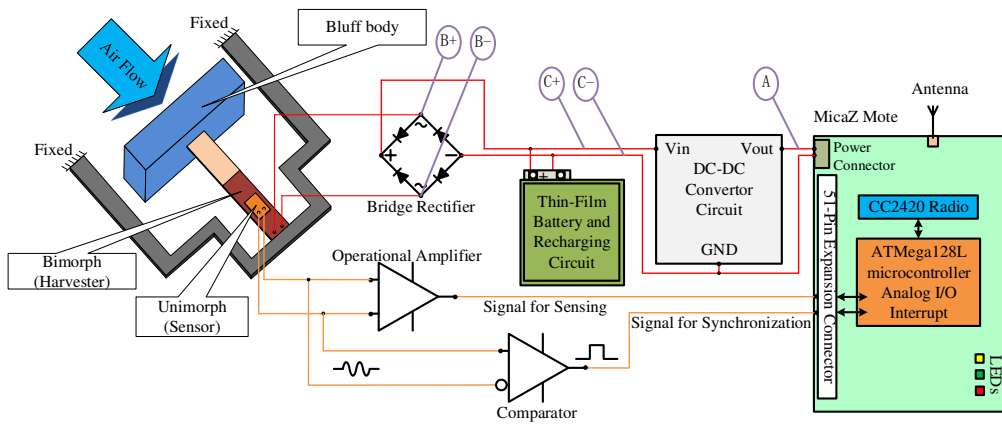


Figure 1: Trinity Indoor Sensing System.

er commonly used nodes. It can be clearly seen that there are three “paths” between the harvester and the node. The upper one is for power supply; it goes through our power management module. The middle one samples the voltage and thus serves as our sensor. The lower one transforms the voltage signal into square waves for synchronization purpose. Since it is difficult to deploy a large-scale network in the exhibition venue to illustrate the synchronization algorithms; we thus omit the synchronization part (including the two complementary algorithms) in this demo.

2.1 Energy Harvesting and Power Management

As our sensor nodes are deployed right beside outlets, drawing power from the airflow issued by the outlets comes in handy. The basic idea behind our energy harvesting scheme is *piezoelectric effect*. Our design (see Figure 1) is to attach a bimorph (containing piezoelectric materials) to a frame fixed on an HVAC outlet such that the bimorph can exhibit forced oscillation under the blow of airflow. Consequently, the oscillation exerts mechanical stress on the bimorph which in turn accumulates electric charges. Our harvester and its key component are shown in Figure 2.

The power generated by the bimorph is imported into a general-purpose power management module. This module regulates the alternating voltage to direct voltage of 3.3V to power the connected MicaZ Mote, while buffering the surplus power (if any) in two thin-film batteries, thereby decoupling the power generation from power consumption.

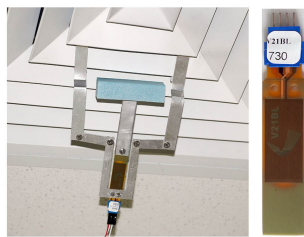


Figure 2: Energy harvester (left) and bimorph (right).

2.2 Energy Free Airflow Speed Sensing

Being an important aspect for indoor microclimate monitoring, airflow sensing can be preformed by many off-the-shelf products. However, these products have a high demand on power beyond the capacity of our energy harvester.

Hence, Trinity takes a novel approach towards sensing the

airflow speed. As the peak output voltage of our harvester is a function of the airflow speed, we may simply sample the voltage of the harvester to infer the airflow speed. In order to avoid being interfered by the node’s operations, we use an additional small piece of unimorph (as shown in Figure 1) to serve the sensing purpose. The sampling procedure involves an amplifier circuit (to proportionally reduce the output voltage) and the ADC module of MicaZ Mote’s MCU; the resulting total power consumption is below $500\mu W$.

3. DEMO OVERVIEW

This is a demo of an associated paper to be presented at SenSys’13 [5]. In this demo, we exhibit the efficacy of our system including energy harvesting and energy-free sensing, but omit the synchronization functionality due to the difficulties in demonstrating. We connect our harvester to a single MicaZ mote through power management module and signal processing unit for sensing. Operating under an extremely low duty-cycle, this node monitors the airflow speeds of an HVAC outlet, and reports them to a sink node which can forward the received report to a PC via serial port.

4. REFERENCES

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