# Wireless Sensor Networks: An Interdisciplinary Topic for Freshman Design

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## Introduction

Wireless sensor networks (WSN) are a nascent technology that builds upon the recent decade's advances in electrical and mechanical engineering including wireless communications, low-power embedded systems, MEMS-sensor design, network architectures and instrumentation applications. These networks promise a means by which to better monitor and understand our industrial, military and natural environments. Wireless sensors have broad interdisciplinary interest and have been recognized as one of the significant emerging technologies by the National Science Foundation[1 2] and the general press [3 4]. Using wireless sensor networks as a motivating technology, this paper discusses a new course for electrical and computer engineering (ECE) and mechanical engineering (ME) freshman at the University of Vermont (UVM). The course provides students with a hands-on experience in which interdisciplinary team work, technical communications and hardware design is emphasized. The engineering program at UVM is relatively small with three departments (electrical and computer, civil and environmental and mechanical engineering) and with ~100 freshman entering each year. Thus the methodology presented herein may serve as a model for similarly sized programs.

## Motivation

In recent years, retention among freshman engineering students at UVM has only been ~60%. To improve retention and attract new students into engineering, faculty from ECE and ME worked to identify components of the freshman curriculum in need of revision. Historically, engineering students at UVM had not been exposed to engineering design until their junior or senior years. This lack of a hands-on design project experience during the freshman year is inconsistent with the curriculum at universities with a strong engineering presence. Thus, a new cross-listed course, EE/ME 001 – *Freshman Design Experience*, was developed in the Fall 2003 and introduced during the Spring 2004. The key objectives of this course were to:

1. Provide students with a better understanding of the electrical and mechanical engineering disciplines. This objective is key for UVM has historically had ~40% of its entering engineering freshman classified as "Undecided Engineering".
2. Provide students with an appreciation for the interdisciplinary nature of engineering, while stressing the importance of structured problem solving.
3. Provide students with an opportunity to develop practical skills through self-motivating, hands-on, team-based design activities. These skills are the same as those required by practicing engineers, namely critical thinking, team-work, and good communication

skills. Moreover, these skills are explicitly specified by the Accreditation Board for Engineering and Technology, Inc. (ABET)[5].

4. Develop a sustainable course structure and requisite infrastructure. A number of previous attempts at UVM have failed to provide a meaningful and sustainable freshman experience.
5. Develop a sense of community among engineering students with the expectation of giving students a feeling of excitement about engineering design and increasing interest in the engineering profession, both of which should improve program retention.

## Wireless Sensor Networks as a Motivating Technology

Clearly the objectives provided above are not unique for freshman or even upper level engineering design courses. The use of wireless sensor networks, however, represents an exciting and self-motivating technology for freshman engineering design projects, which we believe is unique. As noted previously, WSN are a significant emerging technology. Due to its nascent nature, the *Freshman Design Experience* course material exposes students to a field of study that is not typically offered in most undergraduate engineering curricula, let alone at the freshman level.

At UVM, the authors are involved in a number of research and educational projects that are related to WSN. For example, the co-author has developed an outreach program for high school students and teachers entitled "Building and Launching Cricket Satellites." As part of this NSF EPSCoR/HELiX supported program, the participants build and deploy wireless sensors for the purpose of remote environmental monitoring (e.g. temperature, pressure). The wireless sensor and circuitry used in this design is based on an existing, low-cost CricketSat device (Figure 1) originally introduced as part of NASA's Student Satellite Workshop[6].

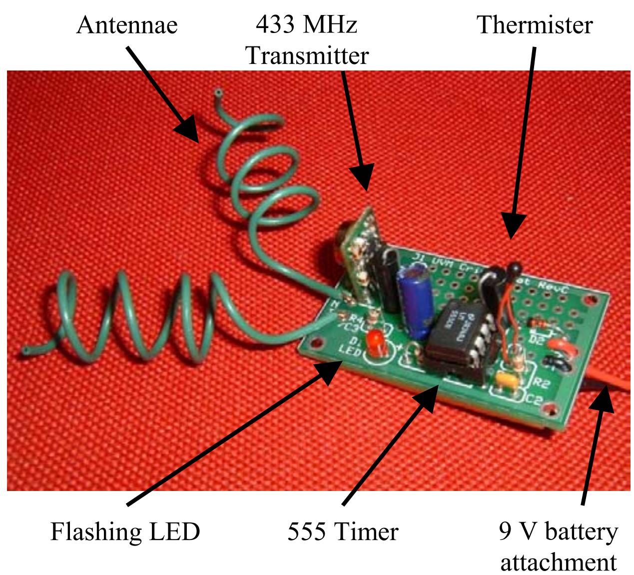


Figure 1. CricketSat configured as a wireless temperature sensor

Other UVM faculty are involved in WSN research programs in a number of areas, including collaborative signal processing techniques (ECE), application-centric quality of service strategies (CS), and applications of such networks for structural monitoring (ME). Furthermore, several local companies are involved in developing WSN components and systems. For example, MicroStrain (Williston, VT), founded by an UVM alumnus, was recently recognized in the press for supplying wireless monitoring equipment used for the recent Liberty Bell move[7]. Hence, the choice of WSN for a motivating interdisciplinary topic is synergistic with a broad range of engineering-related activities in and around UVM. WSN, by nature, are of interdisciplinary interest and thus this emerging technology is deemed appropriate for accomplishing ABET goals and provides an exciting interdisciplinary team experience.

## Course Structure

The two-credit *Freshman Design Experience* course (EE/ME 001) is offered during the Spring semester as a follow-on to ENGR 2: *Graphical Communication* (CAD). EE/ME 001 consists of a 1-hour weekly lecture and a 2.75-hour laboratory session. There is a single lecture section for all students and several labs sections (capped at 20 students each). Both ECE and ME faculty and staff are closely involved with this course ensuring a balanced, interdisciplinary flavor. Teaching assistants from both departments mentor students during the laboratory portion of the course.

### *Lecture Component*

The once a week, one hour lecture component focuses on topics related to the engineering profession, engineering design, electrical-mechanical systems, and wireless sensors networks (Table 1).

**Table 1. Topics for Lecture Component**

| Week | Topic | Week | Topic |
|---|---|---|---|
| 1 | Course Format / Intro to WebCT<br>Brief History of Engineering<br>Electromechanical Systems | 8 | Guest Speaker: *Engineering Design Process, Case Studies* |
| 2 | Engineering Design Criteria | 9 | EE and ME subdisciplines, career opportunities and student organizations |
| 3 | CricketSat design and demonstration | 10 | ASME regional student conference demo |
| 4 | Data collection, analysis and presentation | 11 | Guest Speaker: *WSN Applications* |
| 5 | CAD packages for electrical and mechanical design | 12 | Guest Speaker: *Engineering economics and ethics* |
| 6 | Guest Speaker: *Electromechanical Systems* | 14 | EE and ME senior project presentations and demonstrations |
| 7 | Test procedures and proposal preparation | 15 | Freshman project presentations |

In addition, the freshman are taught the importance of technical communications, data analysis and perform related exercises using computer-based tools. Presentations and demonstrations of Capstone design projects by ECE and ME seniors provide vertical integration with other curricular activities. As noted, ~40% of the College's freshman are declared as

"Undecided Engineering", so lectures also address ECE and ME subdisciplines and career opportunities. This content is complemented by department undergraduate and research laboratory tours. The lecture sections introduce upcoming laboratory activities, discuss completed activities, and provide a forum for talks by technology experts and student presentations. The lecture period is also used as a forum for student engineering organizations such as IEEE, ASME and SWE to give the freshman better insight into their program of study, and how to become involved in the engineering community, and to give students insight as to what to expect in their future years at UVM. Guest speakers from industry discuss real world issues.

Throughout the semester case studies are presented emphasizing the importance of interdisciplinary collaboration and new technologies. An example is a guest lecture on the design of the Segway personal transport device. This product received unprecedented pre-launch publicity and employs the latest in microelectromechanical (MEMS) devices thereby exposing freshman students to topics typically left to graduate courses.

*Laboratory Component*

Table 2 provides an outline of activities performed in the laboratory section of the course. To support these laboratory exercises, students purchase a kit consisting of circuit bread-boarding materials, a low-cost multimeter, dial calipers and assorted electrical components (Figure 2). Students begin the semester performing labs designed to 'explore' the items in their lab kits, including soldering, parts dimensioning and dissecting. Students are also introduced to basic machine shop skills. The next activity involves a low cost electromechanical device that students first experiment with and then dissect. Students conclude this activity by documenting their findings including basic operation of the device, a block diagram of its subsystems, bill of materials and utilized technologies, limitations and ideas for improving the design.

**Table 2. Laboratory Activities**

| Week | Activity | Week | Activity |
|---|---|---|---|
| 1 | Lab kit orientation | 7 | Base CricketSat fabrication |
| 2 | ME shop exercise and soldering | 8 | Follow-on project brainstorming |
| 3 | Product dissection | 9 | Project prototyping |
| 4 | Data analysis activity (Excel/PowerPoint) | 10 | Project fabrication |
| 5 | E-week design competition | 11 | Project test, demonstration and deployment |
| 6 | CAD exercise | 12 | Project presentations |

Approximately one-third of the laboratory activities are dedicated to a design project using an inexpensive wireless sensor/transmitter device, based on the CricketSat (Figure 1). The CricketSat incorporates a 433 MHz transmitter which is driven by a 555 timer whose clock rate is controlled by a parameter sensitive resistance or capacitance (e.g., a thermister for temperature sensing). A commercial receiver is then used to demodulate the transmitted "information" signal. The circuit is easily fabricated, tested and troubleshot and low-cost (~$15). Students are introduced to this design by assembling a wireless temperature sensor. Their assembled devices are tested, calibrated, and then temperature data is recorded, analyzed and documented using a technical report format.


Figure 2. Student Lab Kit

Students then work in teams which must (1) choose and justify an application for which a wireless sensor would be appropriate and (2) design and develop a CricketSat-based system to meet the application's needs bearing in mind any unique constraints it imposes. Each design must both modify the existing circuit design and develop enclosures (including CAD drawings) for their sensor. This activity requires that the students work step-by-step through the design process, including brainstorming, design, fabrication, and test. While the sensors are predominately an electrical device, design applications are interdisciplinary and therefore require both mechanical and electrical engineering skills and knowledge. Previous student designs include a wireless wind-chill instrument (Figure 3 - left), a wireless terrarium climate control system, a wireless door alarm (Figure 3 – right) and a wireless music synthesizer. Student designs are demonstrated, documented and presented by the student teams. Based on peer review, the best design/presentation from each lab section is presented to the class during a final, open forum, lecture period.

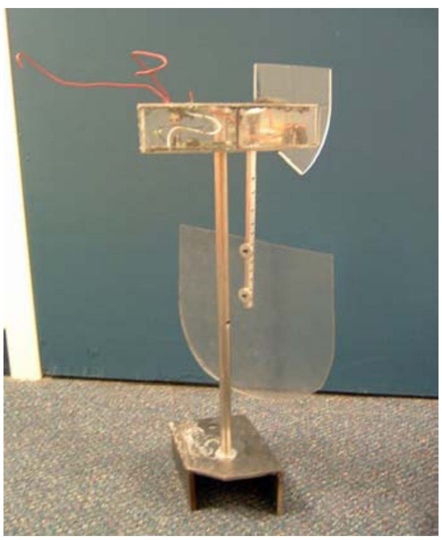

Figure 3. Example student design projects: Wireless Wind-Chill Instrument (left) and Wireless Door Alarm (right)

Evaluation and Results

Since a key course objective was to establish an appreciation for the team-based, interdisciplinary nature of engineering, student assessments include their level of participation. The specific breakdown in terms of grading is as follows: lecture attendance (25%), online quizzes pertaining to lecture material (25%), evaluation of laboratory activities (25%) and faculty and peer evaluations of design projects (25%). WebCT is used to disseminate course material, laboratory assignments and to manage online quizzes and surveys.

Students are also given a number of surveys throughout the semester in order to obtain feedback on their motivation for choosing engineering, the course content and laboratory activities. For example, during the first week of the class, students are queried anonymously as to why they chose engineering, what they would like to learn more about in regards to the discipline (in deference to the large number of undecided students), and what they would like to get out of the course. In addition, students are asked to provide some general information such as the distance from their home to UVM, which is subsequently used as a motivating example for the lecture on data analysis. Students are also queried later in the semester for suggestions on additional lab activities, presentation topics they would like to see and their plans for future studies. Some key findings from the surveys are presented in Table 3.

**Table 3. Key Results from Course Surveys**

| | |
|---|---|
| Students having a **good idea** *after* taking the course of what engineering entails and what practicing engineers do | 36%<br>(an additional 52% already had a good idea) |
| Students more or much **more enthused** about their choice of studying engineering *after* taking the course | 56%<br>(20% less enthused, 24% same level) |
| Course was **too electrical** in focus | 67% (ME respondents)<br>25% (ECE respondents) |
| Were wireless sensors a **good choice** for an interdisciplinary theme? | 53% Yes<br>9% No<br>38% Neutral |

We view the course to be relatively successful in its first offering. We find that both ECE and ME students are more effective in their subsequent labs in comparison to their predecessors. In addition, 84% of the students enrolled in this course continued studies in engineering in their sophomore year, which is higher than the historic UVM rate of less than 60%. However, there is still opportunity to improve the course and its structure. On the project side, one clear finding is that students felt their designs were too electrical in focus given they were based on the CricketSat. While we have students produce mechanical drawings for their designs; these are often done after the fact. For example, Figure 3 – right show the wireless door alarm that utilized a mint box and an empty tooth paste tube. While credited with creative packaging; the CAD drawing developed by this team served no design purpose. As such, we are working to incorporate rapid prototyping technology (RPT) into UVM's curriculum, beginning with this freshman course, as a means of strongly coupling CAD and physical designs. In addition, with the assistance of a grant from HP's Technology for Teaching Program, we are now implementing Tablet PCs to capture the student design activities thus enabling review of their laboratory notebooks with having physical possession of them. We view this as an opportunity to improve design guidance throughout their relatively short project cycle.

## Conclusion

This paper presents a freshman design experience course motivated by the emerging interdisciplinary technology of wireless sensor systems. Using team-based wireless sensor-based designs as a focus, students become familiar with various aspects of design, fabrication and performance assessment that will be utilized throughout their academic and professional careers. The retention results of student in its initial offering exceed historic UVM levels. However, this is a single data point and thus the long term impacts of this course (currently in its second offering) are yet to be determined.

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## BIBLIOGRAPHY

[1] National Science Foundation, *Program Solicitation: Sensor and Sensor Networks* (NSF 04-522).
[2] National Science Foundation, *Program Solicitation: Networks of Sensor Systems* (NSF 05-505).
[3] Technology Review, *10 emerging technologies that will change the world*, Technology Review, February 2003.
[4] Pescovitz, D., *Six technologies that will change the world*, Business 2.0, May 2003.
[5] Accreditation Board for Engineering and Technology (ABET), *Engineering Criteria 2000*.
[6] NASA Space Grant Consortium, *StudentSat Workshop*, online: spacegrant.colorado.edu/studentsat/
[7] NSF Press Release, *Liberty Bell Passes Stress Test*, online: www.nsf.gov/od/lpa/news/03/pr0337.htm

## BIOGRAPHIES

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