Work in Progress: MUSE – Multi-University Systems Education

Jeff Frolik, Tom Weller, Paul Flikkema and Wayne Shiroma
jfrolik@uvm.edu, weller@eng.usf.edu, paul.flikkema@nau.edu, wayne.shiroma@hawaii.edu

Abstract – **An undergraduate track in wireless sensor networks is being developed as a vehicle for learning systems thinking and as an example of complex-engineered designs. This track features (1) online tutorials, (2) a systems-centric, senior technical elective, (3) a culminating Capstone Design course emphasizing inter-university collaboration, and (4) a hardware/software testbed that is distributed across universities. The project is in its first year and results to date are presented.**

Index Terms – Communication systems, Systems engineering, Tablet PC, University partnership.

INTRODUCTION

Today's curricula have failed to cultivate the concept of *systems thinking*, which develops in students the ability to envision architectures of complex-engineered systems and their underlying principles. A typical undergraduate electrical engineering curriculum is segmented into specializations, with little bridging between courses to demonstrate the interplay of concepts in real systems. Yet real engineered systems tend to be complex, multilayered, multifaceted, and interdisciplinary, meaning that systems thinking is critical for future engineering leaders.

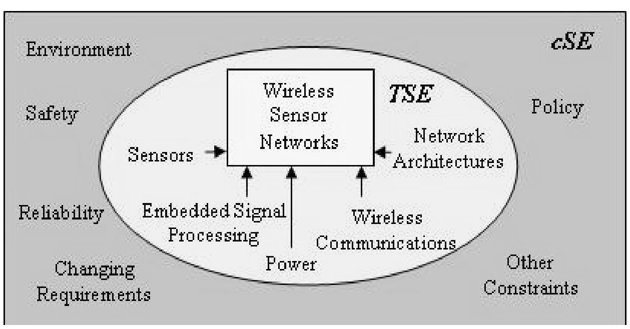

FIGURE 1
WIRELESS SENSOR NETWORKS AS A MODEL FOR SYSTEMS ENGINEERING AND COMPLEX SYSTEMS

As an example of such systems, we utilize wireless sensor networks (WSN) as a theme for the curriculum development to be discussed herein. As illustrated in Figure 1, these networks not only serve as a vehicle for studying traditional systems engineering (TSE) since they integrate numerous core technologies (e.g., sensors, communications, and embedded computing) but also have influence on and are influenced by other factors external to the network (e.g., policy and environment) and thus can also be used as a vehicle for studying complex systems engineering (cSE).

In the NSF-sponsored, MUSE (Multi-University Systems Education) project we contribute to the current educational research base by developing, implementing, assessing, and disseminating a methodology that (1) leverages the expertise of several universities to develop and teach courses that individually they would not be able to, (2) introduces students to a highly relevant interdisciplinary and cutting-edge technology – wireless sensor networks, (3) can readily be incorporated into existing curricula, and (4) makes systems thinking a central aspect of learning. The three-year project is a collaboration of our four institutions and is in its first year. Herein we outline overall scope and progress to date.

MUSE COMPONENTS

The MUSE curricular track features (1) online tutorials on complex-engineered systems, (2) a systems-centric, senior technical elective, and (3) Capstone Design projects emphasizing inter-university collaboration. In addition, a hardware/software testbed that is distributed across universities and provides a standardized infrastructure for project continuity is in development.

I. Online Tutorials

On-line tutorials are to be used to introduce junior year students to systems thinking and the field of wireless sensor networks. The tutorials will present case studies to demonstrate how systems engineering relates to complex-engineered systems.

To develop these tutorials, we are utilizing Tablet PCs and Camtasia Studio software to capture the screen content along with audio. The methodology enables the flexibility of content type between slides, simulation, hand-developed expressions, etc., all of which are easily marked up using Tablet features. Planned tutorials include *What is Systems Engineering?*, *Introduction to Wireless Sensor Networks*, and *Case Study: The Segway*. The tutorials will include integrated, interactive quizzes to ensure students indeed learn the tutorial content.

II. Collaborative Course: Wireless Sensor Network Design

In this course, students develop in-depth technical understanding of the multiple subdisciplines required for the design of wireless sensor networks. This rigorous, three credit-hour class is to be offered as a technical elective at the collaborating universities. Students study online modules (developed much as the tutorials are) and meet with the instructor once a week for a just-in-time-teaching (JiTT) discussion session. The discussion sessions are used to elaborate on concepts related to the PI's particular discipline, conduct demonstrations, and foster discussion regarding the real-world application of concepts. To enhance the JiTT discussions, the PIs conference call weekly to discuss issues related to student learning (e.g., results of interactive quizzes), to develop content for the discussion sections (e.g., sample applications from other disciplines) and to update module content based on student feedback.

TABLE I
TABLE OF CONTENTS FOR VIRTUAL TEXTBOOK

Chapter	Title
1	Overview: Why Wireless Sensor Networks?
2	Systems Engineering Applied to WSN
3	Transducers
4	Analog-to-Digital Conversion
5	Radios – The Wireless Interface I (Hardware)
6	The Wireless Channel – Point-to-Point Communications
7	Radios – The Wireless Interface II (Methods)
8	Networking
9	Managing the Sensor: Embedded Computing
10	Bringing It All Together – More Systems Engineering

TABLE II
EXAMPLE CHAPTER CONTENT: 6 – THE WIRELESS CHANNEL

Summary	Propagation fundamentals. Best case scenario: free-space and the Friis equation. Large-scale phenomena: reflection, diffraction and scattering. Small-scale phenomena: multipath resulting in time-, space – and frequency-selective fading effects. Fading models and diversity methods. Uniqueness of wireless sensor application in comparison to mobile communication systems. Diversity methods. Link budgets.
Example	Research using receive signal strength indication (RSSI) to monitor channel performance: Wireless Sensing, Sensing Wireless (WSSW)
Objectives	• Understand the fundamentals associated with free-space propagation loss. *Links to traveling electromagnetic waves*. • Be able to define key sources of propagation effects both and the large- and small-scale. *Leverages probability and statistics*. • Be able to define basic diversity schemes to mitigate small-scale effects. • Understand key differences between the channel for mobile communication systems and that for wireless sensor networks. • Be able to develop a link budget for a wireless sensor application including margins for large- and small-scale propagation effects. *Links to antenna and radio performance*.
Complex Systems	Complexity of implementing diversity scheme where communications is to one of many different points and each communication has its own unique fading.

The online tutorials form a virtual textbook for the course (Table 1). The uniqueness of this course comes not from simply presenting subsets of information from existing courses, but from developing these concepts within the context of the engineering of complex systems. As such, the course content and objectives link to concepts covered in other courses from both within and outside engineering, found in related research, or pertaining to broader issues (Table 2).

III. Capstone Design and Hardware/Software Testbed

A project testbed will be developed at each of the collaborating institutions and will comprise software, hardware, and instrumentation that results from student-developed subsystems. Student projects will include novel sensors, tools for data acquisition and human interface, power distribution and conditioning, packaging, and automated sensor testing. The testbed infrastructure will be engineered to well-defined standards (operating systems, connector types, signal levels, etc.) to constitute a pool of easily adopted components for testbeds at other institutions. This emphasis on design standards is appealing for several reasons. First, student participation in defining these standards will provide real-world experience in system-level specification. Second, the proposed approach will aid the longevity of the program and enable increasing levels of complexity in the types of projects that are attempted in subsequent years. Our experience gained from a prototype course highlights the difficulty in successfully executing the design, development, and testing of a complete system in one semester and thus our testbed approach is one where students contribute to an evolving wireless sensor system.

PROGRESS TO DATE

The collaborative course, *Wireless Sensor Network Design*, is being offered for the first time this fall (2008) at Northern Arizona University and the University of South Florida. At the FIE conference, curricular modules will be demonstrated and initial assessment results (of student learning and of delivery method) will be presented. The authors invite reader feedback regarding adoption of course materials and evaluation of the MUSE project as a model for multi-university curricular collaboration. These and future results can be found online at www.uvm.edu/~muse.

CONCLUSION

Our objective with this paper is to increase awareness of the MUSE Program and to attract additional adopters of the deliverables. As the project progresses, these materials will include a development guide for multi-university curriculum design, curricular products specific to the wireless sensor network track, and complete assessment tools for both student learning and university collaboration.

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AUTHOR INFORMATION

Jeff Frolik, Associate Professor of Electrical Engineering, University of Vermont; **Tom Weller**, Professor of Electrical Engineering, University of South Florida; **Paul Flikkema**, Associate Professor of Electrical Engineering, Northern Arizona University; **Wayne Shiroma**, Professor of Electrical Engineering, University of Hawaii.