
AC 2012-4722: INTEGRATION OF WIRELESS SENSOR NETWORKS IN THE COMPUTER SCIENCE AND ENGINEERING CURRICULA

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Integration of Wireless Sensor Networks in the Computer Science and Engineering Curricula

Abstract

Recent, development in wireless networks, micro electro-mechanical systems (MEMS) technology, and digital electronics have led to the emergence of Wireless Sensor networks (WSNs). A wireless sensor network consists of spatially distributed autonomous sensors that cooperatively monitor physical or environmental conditions, such as temperature, light, sound, vibration, pressure, motion or pollutants¹. These networks consist of small battery-powered motes with limited computation and radio communication capabilities. Each sensor in a sensor network consisting of three subsystems: the sensor which senses the environment, the processing subsystem which performs local computations on the sensed data, and the communication subsystem which is responsible for message exchanges with neighboring sensors.

Wireless Sensor Network is an active area of research with numerous applications. Some of the applications of WSNs includes homeland security, health care system, monitoring of space assets for potential and human-made threats in space, ground-based monitoring of both land and water, intelligence gathering for defense, environmental monitoring, urban warfare, weather and climate analysis and prediction, battlefield monitoring and surveillance, exploration of the Solar System and beyond, monitoring of seismic acceleration, temperature, wind speed and GPS data².

A quality education requires exposing students to the current edge of research and technology. To ensure that student projects are complementary to industrial development, educators must continually introduce emerging techniques, technology, practices, and applications into their curriculum. The field of wireless sensor networks is growing rapidly and has captured the interest of various sectors. The increasing popularity of WSN has motivated universities to provide students with a foundation in the area. It is crucial that the emerging field of wireless sensor networks be integrated into the computer science and engineering curriculums. This paper studies the different approaches that are used by different institutions of higher education around the world to integrate wireless sensor networks concepts into their curriculum.

Introduction

A wireless sensor network (WSN) is a network of a set of independent small nodes equipped with sensor(s), a wireless radio, a battery, and an on-board processor. Usually, the unit that consists of the wireless radio and the on-board processor is called a mote. With the recent advances in MEMS technology, wireless communications, and digital electronics, the design and development of low-cost, low power, multifunctional sensor nodes that are small in size and communicate untethered in short distances have become feasible. The ever-increasing capabilities of these tiny sensor nodes, which include sensing, data processing, and communicating, enable the realization of wireless sensor networks (WSNs) based on the collaborative effort of a large number of sensor nodes.²

A wireless sensor network consists of a large number of wireless-capable sensor devices working collaboratively to achieve a common objective. A WSN has one or more sinks (or base-station) which collect data from all sensor devices. These sinks are the interface through which the WSN interacts with the outside world.³ The basic premise of a WSN is to perform networked sensing using a large number of relatively unsophisticated sensors instead of the conventional approach of developing a few expensive and sophisticated sensing modules.³ The potential advantage of networked sensing over the conventional approach, can be summarized as greater coverage, accuracy and reliability at a possibly lower cost.³

WSN networks have the potential to interface the physical world with the virtual (computing) world on an unparalleled scale and provide practical usefulness in developing a large number of applications, including the protection of civil infrastructures, habitat monitoring, precision agriculture, toxic gas detection, supply chain management, and health care. However, the design of wireless sensor networks introduces formidable challenges, since the required body of knowledge encompasses a whole range of topics in the field of electrical and computer engineering, as well as computer science.⁴

The sensor networks can be used for various application areas (disaster recovery, health, military, homeland security, environment, home, etc.).⁵ For each application area, there are different technical issues that researchers are currently resolving. Open research issues and challenges are identified to spark new interests and developments in this field.⁸

“The concept of WSN was proposed by the U.S. military as early as 1970’s”.⁶ MIT’s Technology Review stated in 2003 that the WSN is one of the top ten emerging technologies for the 21st century and has been developing at an accelerated pace in the past ten years⁶. Since wireless sensor networks are becoming increasingly popular, much research has been done to push it forward, however; there are still many challenges existing for wireless sensor networks. Typical ones include the unreliable wireless communication systems, limited power availability, failure of nodes, large- scale deployment.

Educational excellence requires exposing students to the current edge of research. To ensure that student projects are along the same trajectory that the industry is moving, educators must continually introduce emerging techniques, practices, and applications into the curriculum. The field of wireless sensor networks is growing quickly, and there is an increasing interest in providing students with a foundation in the area. It is crucial that the emerging field of wireless sensor networks be integrated into the computer science and engineering curriculums.

Undergraduate WSN Course at Portland State University

In the Computer Science Department at Portland State University, they introduced an in-class laboratory component to their undergraduate sensor networks course that had previously been entirely lecture-based. For the laboratory exercises, they used Sun’s Java-programmable Sun SPOT sensor network technology. They found that their first hands-on laboratory-based undergraduate-accessible wireless sensor networks course to be a success. They feel that the gentler learning curve of the SPOTs was a necessity for developing labs that reinforce important

concepts from the lecture, and this would have been impossible if students were required first to learn TinyOS and NesC.⁷

Undergraduate WSN Course at University of Lugano

At the University of Lugano's Computer Science Department, they have developed a new undergraduate course called "Introduction to Wireless Sensor Networks." They used a purely hands-on approach to teaching this course. They believe that a purely hands-on approach is crucial for fully understanding the complex nature of Wireless Sensor Networks. Their overall experience with this new course was very positive. Their students were very motivated, and most of them completed their project assignments. They used Scatterweb's MSB430 Sensor platform. The hardware was well suited for their needs. The employment of this class allowed their students to develop clear expertise in WSNs by creating their own WSN system.⁸

Undergraduate WSN Course at University of Twente

At the University of Twente, in order to attract more students into their Embedded Systems track, they have designed an undergraduate course on Wireless Sensor Networks. Their goal was to create a course on WSNs that provides meaningful insight into the subject. To enable their students to do practical experiments Sun SPOT Development kits were used. These kits contain JAVA programmable wireless sensor nodes. Their preliminary conclusion is that the new set up was very successful. All of their students were able to finish their assignments, which clearly show that their set educational goals were achieved⁹.

Undergraduate WSN Course at University of Washington

At the University of Washington's Department of Computer Science and Engineering (UW CSE), they have integrated the concepts of wireless sensor networks into their undergraduate computer engineering curriculum. In their Software for Embedded Systems (CSE 466) course which exposes their students to the design issues that characterize embedded systems, they require a project that addresses the complexities of embedded systems within the constraints of a 10-week course. They wanted to create a class-wide project where students can contribute individually. To meet their course objectives by combining sound generation with emergent behavior in an ad hoc network, they designed the "Flock of Birds" project which is a simple distributed system. Each student programmed a mote to act as a bird that had several songs stored in its local memory. The programs executed a common rule base, but each bird acted independently – deciding which song to sing based on what the other birds within radio range were singing. In combination, the songs created the sound a flock of birds made. They selected the Crossbow (www.xbow.com) Mica2Dot platform. The project succeeded from an instructional perspective – integrating communication protocols, constrained resources, hardware control, and a novel application that required students' projects to interact¹⁰.

Undergraduate / Graduate WSN Course at University of San Francisco

In the computer science department at the University of San Francisco (USF), they have developed a course in wireless sensor networks for their undergraduate and introductory graduate

students. The computer science department at USF is similar to that of many liberal arts colleges. The wireless sensor network course at USF introduces several general computing concepts using wireless sensor networks as an overarching example application. The course takes a networking-centric approach to WSN. Their course uses Sun's Small Programmable Object Technology (SPOT) sensor platform. The SPOT sensor platform is a Java-programmable sensing device that comes equipped with a light sensor, accelerometer, and a temperature sensor. Their general observation is that their unique approach of integrating distributed systems, networking, and WSN concepts into the same course has been successful¹¹.

Wireless Sensors at the University of Vermont

At the University of Vermont, they have an ongoing program to utilize wireless sensors networks to enable new laboratory and field experiences in a wide variety of courses which supports multiple engineering disciplines. Their effort to utilize wireless sensors for hands-on activity started in 2004 with their first year design course. In this course they utilized CricketSat wireless sensor as a project platform. In the fall of 2006, the department started offering a Senior/Graduate course on Wireless Sensor Networks which utilizes commercial wireless sensors to develop networks for custom applications. In their Mechanical Engineering Lab III, they have integrated commercial wireless sensors for beam mechanics and vibration monitoring. In their department of Civil Engineering and Environmental Science, they are using commercial wireless sensors for the acquisition and analysis of environmental and traffic data obtained in their Modeling Environmental / Transportation Systems course. They have developed a course called Sensors and Circuits which is required for all their engineering majors. In this course, they have integrated the development of a USB-based sensor platform.¹²

Multi-University Systems Education (MUSE) Project

In order to prepare undergraduate engineering students for highly complex engineering problems, engineering education needs reform. Multi-university system education (MUSE) is a project sponsored by the National Science Foundation as a step toward engineering education reform. The goal of this project is to develop innovative approaches for engineering education. They have proposed a learning model that develops important skills that is not addressed in the contemporary engineering curricula. This model's emphasis is to teach system thinking skills to undergraduate students. Systems thinking enable students to envision the architecture of complex, multi-layered engineering systems¹³.

In this project, an undergraduate track in wireless sensor networks has been developed as a vehicle for studying these systems, featuring (1) junior-year tutorials, (2) an online, systems-centric, senior technical elective, and (3) a culminating Capstone Design course emphasizing inter-university collaboration¹⁴.

They have developed a series of hands on hardware-based and simulation-based experiments designed to emphasize systems thinking as related to wireless sensor networks. In the Fall of 2009, two universities utilized these material, and in Spring of 2010, two more universities utilized these materials. The authors are actively looking for adopters for the online materials and experiments¹³.

Models for Integration of Wireless Sensor Networks in Curriculums

Table 1 provides a study of wireless sensor networks course offerings of selected universities in the world. Course offerings of twenty five universities were studied. From this study it can be seen that universities are using five models to integrate wireless sensor concepts into their computer science and engineering curriculum:

1. Offering an undergraduate course on Wireless Sensor Networks.
2. Offering a graduate course on Wireless Sensor Networks.
3. Integrating Wireless Sensor Networks concepts into their traditional courses.
4. Offering an undergraduate track in Wireless Sensor Networks.
5. Requiring a Wireless Sensor Networks project in a Capstone course.

Model 1 is used by several universities such as the University of Lugano, Lehigh University, and Yale University. Out of twenty five universities studied, nine are offering an undergraduate course on Wireless Sensor Networks. The majority of universities that have graduate programs are offering graduate courses on Wireless Sensor Networks. Some universities are using the third model and integrating Wireless Sensor Networks concepts as modules into their existing courses, as seen by the Massachusetts Institute of Technology, Stanford University, the University of Vermont, and Drexel University. There are various universities that are working on incorporating applied wireless sensor networks in their existing embedded systems courses such as the University of California Davis and the University of Washington. In the MUSE project, an undergraduate track in wireless sensor networks has been developed as a vehicle for studying these systems, featuring (1) junior-year tutorials, (2) an online, systems-centric, senior technical elective, and (3) a culminating Capstone Design course emphasizing inter-university collaboration¹⁴. At Seoul National University, they are using model five and requiring a wireless sensor network project for their capstone course.

Utah Valley University

Utah Valley University (UVU) is a state institution with 23,840 students. UVU is located in Utah County, which has a population of over 430,000 residents. The Computer Science department at UVU offers a Bachelor's Degree in Computer Science with four areas of specialization, including Computer Science (traditional), Computer Engineering, Database Engineering and Computer Networking. The Bachelor of Science in Computer Science program was one of the first Bachelor of Science programs implemented at UVU in 1993. The program's goal has been to provide a quality program that meets accreditation standards while providing the students with a skill set that allows them to succeed in computing careers. The curriculum content for the Computer Science degree is based on the 2008 ACM Curriculum Report. The Computer Science degree at UVU is accredited by Accreditation Board for Engineering and Technology (ABET) in 2002 and currently has more than 500 students. To integrate wireless sensor networks concepts into our curriculum, we decided to use the third model and integrated wireless sensor concepts in our Embedded Systems Design class. In order to interest students in the subject of Wireless Sensor networks, they are required to write a paper on the topic of

Wireless Sensor Networks. As a result of this assignment, many students have started to do their senior design project on this subject.

	Undergraduate Wireless Sensor Network Course (WSN)	Graduate Wireless Sensor Network Course	Wireless Sensor Network Concepts as a Module in Other Classes	Comments
Portland State University⁷	An activity-based Sensor Network Course (CS)			Using Sun Spot Devices
University of Lugano⁸ (Switzerland)	Introduction to Wireless Sensor Networks (CS)			Using MSB430 Sensor Nodes
University of Twente⁹ (Netherlands)	Wireless Sensor Network (CS)			Using Sun Spot Devices
University of California, Davis¹⁶	EEC 172 : Embedded Systems (CE)			
University of Washington¹⁰	CSE 466: Software for Embedded Systems			
University of California, Berkeley¹⁷	EE290Q: Introduction to Wireless Sensor Networks			
Massachusetts Institute of Technology¹⁸		CS 428: Information Processing for Sensor Networks	6.266 – Network Algorithms 6.268 – Network Science and Models	
Harvard University¹⁹	CS 263r: Wireless Sensor Networks			
Stanford University²⁰	CS 321: Information Processing for Sensor Networks		CS 433B: Advanced Wireless Networks	Stanford WSNs Lab ²⁴
Carnegie Mellon University²¹	None in CE or EE	18-748: Wireless Sensor Networks ¹⁷		
University of Utah²²	None in ECE or CS	None		
Stony Brook University²³		CSE 590: Algorithms for Wireless Sensor Networks		
Yale University²⁵	EENG 460a: Networked Embedded Systems and Sensor Networks			
University of Virginia²⁶		CS 851: Large Scale Deeply Embedded Networks		
University of Southern California²⁷		CSCI 652/EE652: Wireless Sensor Networks		
Lehigh University²⁸	CSE 498-11: Wireless Sensor Network Design			
University of Leeds²⁹	Wireless Sensor Networks and Location Systems			
Arizona State University³⁰		Wireless Sensor Network	Digital Signal Processing course	IMPACT mobile computing lab
University of	ELEC 4000/ENGG			

Queensland ³¹	7300: Wireless Sensor Network			
University of Vermont ¹²	CS/Engineering: Wireless Sensor Network	Wireless Sensor Network	First Year Design Experience; Mechanical Engineering Lab III; Modeling Environmental/ Transportation Systems; Sensors & Circuits.	
Utah Valley University ³²	No	No	No	
Drexel University ³³			ECE-C490: Wireless Embedded Networks Lab ECE-S435: Digital Signal Processing II ECE-S690: Statistical Pattern Recognition	
Lamar University ³⁴	No	No		
University of Houston Clear Lake ³⁵	No	No		
Seoul National University ³⁶				Capstone Design Project in WSN

Table 1: A Survey of Universities with Regard to Wireless Sensor Networks Offerings

Summary and Future Research:

Wireless sensor networks is a key technology for ubiquitous systems. The future widespread availability of wireless sensor networks requires application designers and embedded engineers to be familiar with it and its emerging standards. Even though interest in wireless sensor networks has been increasing amongst the computer scientists and engineers in recent years, institutions that offer courses dedicated to the topic are still in the minority. The courses that are offered in this area are mostly designed and taught at the graduate level. The Integration of Wireless Sensor Networks concepts in undergraduate computer science and engineering have started slowly in many universities worldwide.

When should wireless sensor networks concepts be introduced into computer science and engineering curriculum? Some scientists believe that it should be introduced as early as possible, which is the approach taken by the University of Vermont²⁸. Their First-Year Design Experience course is required for both electrical and mechanical engineering students and utilizes wireless sensor systems to motivate an interdisciplinary introduction to engineering. Some believe that it should be offered as a senior level required course. The second option might be harder to implement, since adding a new course to the curriculum is not an easy task, as often times

eliminating another course would be necessary. Offering it as an elective course is not a good option either, since every student is not going to get this experience. It seems that adding the concepts slowly as modules to existing courses is a good solution for integrating the wireless sensor networks concepts into the computer science and engineering curriculums, which is the approach taken by Drexel University³⁴.

As the industry is constantly involved in the development of technology and products to solve issues with wireless sensor networks, tomorrow's computer scientists and engineers must be educated on the wireless sensor networks concepts. As educators, teaching wireless sensor concept today is vital to giving our undergraduate students the system thinking skills which enables our students to envision the architecture of complex, multi-layered engineering systems. It is crucial that wireless sensor networks topics be integrated into undergraduate computer science and engineering curricula.

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