Final Report for the NSF CCLI Project (DRAFT, October 14, 2009)

1. Project Title:

   Collaborative Research: Module-based Courseware and Laboratory Development for Teaching Secure Wireless Sensor Networks

2. PIs of the Project:

   Dr. Toneluh Andrew Yang (University of Houston Clear Lake, Award number: 0633469)

   Dr. Bo Sun (Lamar University, Award number: 0633445)

3. Duration of the Project:

   4/1/2007 – 12/31/2009

   Note: The original project duration, 4/2007 – 3/2009, was extended to 12/2009 in order for the PIs to complete the proposed tasks.

4. Brief Description of the Project

   The project is collaboration between Lamar University and University of Houston Clear Lake. The PIs proposed the development of educational materials for teaching Wireless Sensor Networks (WSN) tailored for undergraduate students by using real-world WSN applications as case studies and avoiding complex theoretical discussions and mathematics. Major outcome from the project include courseware modules and labs. The courseware modules were designed as self-contained teaching units for specific topics in wireless sensor networks; the modules and the accompanying labs together should help interested instructors of relevant computer science or engineering courses to introduce topics of wireless sensor networks by adopting relevant modules. The modules are supplemented by a sequenced set of hands-on laboratory projects, which allow the students to explore the various aspects of wireless sensor networks, from the introductory lab of learning the Tiny OS version 2 to more advanced labs covering the security and energy management of wireless sensor networks. The PIs have performed both formative and summative evaluations of the developed modules, and have conducted a workshop to disseminate the modules and labs. Referred publications and Web sites are also used as dissemination tools of the research findings.

5. Goals of the Project

This project has two primary goals: (a) To develop an educational infrastructure at University of Houston-Clear Lake and Lamar University for teaching wireless sensor networks and their security solutions in undergraduate computer science and engineering curricula; (b) To establish a courseware repository where computer security and wireless sensor network modules and related educational materials may be collected, and freely accessible by educators, students, and the general public.

6. Results of the Project

Major outcomes of the project include nine course modules, a set of labs, assignments, and projects, three assessment instruments and the respective assessment results, Web sites for disseminating the project, four refereed publications, two working papers, one workshop, and three presentations.

6.1. Educational Materials

The PIs have developed nine practical modules to teach secure wireless sensor networks.

1. *Introduction to Wireless Sensor Networks;*

2. *TinyOS;*

3. *Energy Management;*

4. *Radio and Medium Access Control (MAC);*

5. *Wireless Link Estimation;*

6. *Data Collection and Dissemination;*

7. *Security of Wireless Sensor Networks;*

8. *Localization and Secure Localization;*

9. *Aggregation and Secure Aggregation.*

Relevant assignments, labs, and projects were also developed to facilitate students' understanding of those modules.

The following Web sites have been used to disseminate the modules: http://sce.uhcl.edu/yang/public/Modules.html.

6.2. Assessment Instruments

In order to assist the development of the WSN modules, both formative and summative evaluations were performed to improve the development process.

6.2.1. Formative Assessment Instruments

To evaluate the whole set of the modules, the following instrument (Table 1) was used; the instrument is composed of four criteria and relevant evaluation questions. Based on the results and comments made by the internal evaluators, the modules were revised to remove the identified deficiencies.

Table 1. The instrument for formatively evaluating the whole set of modules

Criteria	Evaluation questions	Evaluation results & comments
1) The set of modules should cover sufficient topics with respect to the chosen subject.	a) Are the topics covered in the modules sufficiently comprehensive with respect to the subject?	
2) The set of modules should form a structured sequence of learning units.	b) Are the prerequisite relationships, if any, between the modules clearly defined?	
3) The overall design of the modules should encourage collaboration among students.	c) Are sufficient collaborative activities/projects built into the modules?	
4) The design of the modules should consider students with diversified capabilities and strengths.	d) Are the modules designed in such as a way that students may tackle modules of various level of difficulty?	

For each of the modules, another instrument (Table 2) was developed to formatively evaluate the module. Six criteria and a set of relevant evaluation questions were applied to each individual module to ensure that each module is a self-contained, easy to adopt teaching unit. After the formative evaluation, each module is revised according to the evaluation results.

Table 2. The instrument for formatively evaluating an individual module

1. For each of the modules:	**Module number and name:** Module x: …	
Criteria	**Evaluation questions**	**Evaluation results & comments**
1) Sufficient details should be provided to the students in order for them to 'execute' the project(s) in the module.	a) Are the required hardware, software, and their configurations clearly explained in the modules? b) Is the description of each module free from typos and grammatical errors?	
2) The module should be defined in such a way that	c) Does the module provide sufficient information for students to reach the	

the learning objectives are met once the student has satisfactorily completed the module.	anticipated learning objectives? d) Is the set of activities in the module sufficient to reach the anticipated learning objectives?	
3) The size of each module should be appropriate such that it could be completed within reasonable amount of time.	e) Does the size and level of difficulty of the module allow most students to complete it within 5-10 hours?	
4) Both fundamental and practical knowledge and skills should be addressed in a module.	f) Does the module contain balanced materials for students to acquire both fundamental and practical knowledge and/or skills?	
5) The *entry requirements* of a module should be clearly defined.	g) Are the prerequisite knowledge and/or skills of the module clearly defined?	
6) When feasible, a module should be *independent*, meaning that it can be taught all by itself without requiring a prerequisite set of modules to be used first.	h) Can relevant module alone (without other accompanying modules) be adopted by an instructor in his/her teaching?	

Information about the assessment instruments, including the original modules, the evaluation results, and the revised (current) modules, are available from http://sce.uhcl.edu/yang/public/evaluations/ModuleEvaluation.html.

6.2.2. Summative Assessment Instruments

While formative evaluations as described above were used to refine the course modules during the development process, summative evaluations were performed while the modules were actually used by instructors in teaching wireless sensor networks. The instrument the PIs developed for the purpose of summative evaluation of the modules is in the form of student survey. Table 3 shows the instrument, which is composed of three categories and 17 evaluation questions. The instrument was used in two different classes; the results in Table 3 were collected from one of the classes taught in summer 2008.

Students answered each of the evaluation questions by choosing a score on the scale of 1 to 5, with 5 being Strongly Agree and 1 being Strongly Disagree. As shown in Table 3, the feedback from students about the course modules was very positive.

Table 3. Student Evaluation

Categories	Evaluation Questions	Average	Standard

		Score	Deviation
• General Questions	1) I have learned a great deal from this class.	4.72	0.467
	2) Students have the opportunities to be exposed to practical aspects of wireless sensor networks.	5	0
• Questions about the Project	3) The project is necessary in this class.	5	0
	4) The project in this class is challenging.	4.72	0.467
	5) The project in this class is very interesting.	4.9	0.301
	6) The project in this class requires a lot of skills to finish.	4.5	0.505
	7) The project in this class is time-consuming.	4.5	0.505
	8) The project is a valuable part of this class.	4.72	0.467
	9) The project used in this class helps me improve my ability of problem solving.	4.8	0.405
	10) The project used in this class helps me improve my ability of creative thinking.	4.73	0.467
	11) The project used in this class helps me improve my ability of independent thinking.	5	0
• Questions about the Course Modules	12) The course materials covered in this class are difficult.	4.36	0.501
	13) It is time-consuming to understand the course materials.	3.72	0.905
	14) The course materials used in this class help me improve my ability of problem solving.	4.81	0.405
	15) The course materials used in this class help me improve my ability of creative thinking.	4.81	0.405
	16) The course materials used in this class help me improve my ability of independent thinking.	4.54	0.505
	17) The time spent in this class is worthwhile.	5	0

6.2.3. Online Assessment

As an alternative evaluation method of the developed modules, the PIs are currently developing an online evaluation system to assess how the modules published at http://www.dcsl-uhcl.net/public/Modules.html are used by the public. Other features such as discussion groups will also be set up to facilitate online user discussions.

6.3. Web sites

6.3.1. The following Web site was used in presenting a 2009 ACM SIGCSE workshop "Teaching Application Development of Wireless Sensor Networks using Motes and Sensors": http://galaxy.cs.lamar.edu/~bsun/sigcse_09/sigcse_09.html

6.3.2. The following Web sites have been used to disseminate this project:

http://sce.uhcl.edu/yang/public/Modules.html

6.3.3. Reference links from the National Science Digital Library (NSDL) were added for the public to access the developed modules: http://nsdl.org/search/?n=10&q=sensor&Submit=Search&include_collection[]=oai%3Ansdl.org%3Ancs%3ANSDL-COLLECTION-000-003-111-905&s=0&verb=Search. The link is also listed under http://nsdl.org/collection/computer-science/.

6.4. Related publications

Published and working papers are attached as the Appendix of this report.

6.4.1. Published and Accepted Publications

T. Andrew Yang, Vishal S. Jadhav, Darshan Chipade, and Bo Sun, "Web 2.0 as an Enabler of Developing Open Content Online Hypertextbooks," accepted to IASTED International Conference on Computers and Advanced Technology in Education (CATE 2009), St. Thomas, US Virgin Islands, November 22-24, 2009.

Bo Sun, Lawrence Osborne, and T. Andrew Yang, "Module-based Courseware for Teaching Secure Wireless Sensor Networks," accepted to IASTED International Conference on Computers and Advanced Technology in Education (CATE 2009), St. Thomas, US Virgin Islands, November 22-24, 2009.

T. Andrew Yang, Deepesh Jain, and Bo Sun, "Development of emulation-based projects for teaching wireless sensor networks". Journal of Computing Sciences in Colleges, 24(2). Consortium for Computing Sciences in Colleges. Dec. 2008. pp. 64-71.

T. Andrew Yang and Dinesh Reddy Gudibandi, "Teaching Wireless Sensor Networks by Incorporating Reorganization Algorithms into the Labs". Journal of Computing Science in Colleges, 23(4). Consortium for Computing Sciences in Colleges. April 2008. pp. 80-88.

6.4.2. To-be-submitted articles

Bo Sun, Lawrence, and T. Andrew Yang, "WSNED – A Suite of Data Collection and Dissemination Applications for Wireless Sensor Network Education", to be submitted to

the South Central Regional Conference of the Consortium for Computing Sciences in Colleges (CCSC), Austin, TX, 4/23 – 4/24/2010.

T. Andrew Yang and Bo Sun, "DEVELOPING AND EVALUATING COURSEWARE MODULES - Experience of teaching wireless sensor networks", to be submitted to the South Central Regional Conference of the Consortium for Computing Sciences in Colleges (CCSC), Austin, TX, 4/23 – 4/24/2010.

6.5. Presentations and workshops

B. Sun, and T. Andrew Yang, "Teaching Application Development of Wireless Sensor Networks using Motes and Sensors", workshop proposal presented at 40th ACM SIGCSE 2009, March 4-7, 2009, Chattanooga, TN.

T. Andrew Yang, "Development of emulation-based projects for teaching wireless sensor networks", presented in the Tenth Annual Northwestern Regional Conference Consortium for Computing Sciences in Colleges, Ashland, Oregon, October 10-11, 2008.

Bo Sun, "Module-based Courseware and Laboratory Development for Teaching Secure Wireless Sensor Networks", presented at NSF CCLI PI meeting, Washington DC, August 2008.

T. Andrew Yang, "Teaching Wireless Sensor Networks by Incorporating Reorganization Algorithms into the Labs", presented in the Sixth Annual CCSC Mid-South Conference, at Arkansas Technical University in Russellville, Arkansas April 4-5, 2008.

7. Conclusion and Future Work

The PIs have successfully realized the two goals specified in this NSF CCLI project. 1) A courseware has been created and freely accessible by educators, students, and the general public; 2) An educational wireless sensor network infrastructure at University of Houston – Clear Lake and Lamar University has been created to teach wireless sensor networks. In addition, formative and summative evaluations were employed to evaluate the developed modules, which were revised according to the evaluation results. The PIs have also disseminated our project through publications, workshop, presentations, and related Web sites. In summary, the PIs have successfully completed this project.

As a potential extension of this project, the PIs plan to develop an online open content hypertextbook for teaching Wireless Sensor Networks. A *Hypertextbook* is an online version of the traditional textbooks. Different from a hardcopy textbook or an e-book, a Hypertextbook is similar to a Web-based system, which provides attractive features such as dynamic interactions, multimedia presentations, animations of important concepts and procedures, and pervasive availability wherever Internet is accessible. Hypertextbooks may be adopted in traditional classroom teaching, but distance education and Web-based education in particular can greatly benefit from the dynamic and user friendly features provided by Hypertextbooks. *Open Hypertextbooks* combine the merits of Hypertextbooks and features provided by Web 2.0 technology, especially the collaborative authoring

process and the collective intelligence resulting from that process. The result is an open content online textbook with not only rich features typically available in a conventional textbook but also flexibility allowing user contribution by adding and/or changing the content of the book. The PIs have developed a prototype version of the Open Hypertextbooks for Wireless Sensor Network; they plan to propose the complete development, evaluation and dissemination of the open Hypertextbook as a NSF CCLI Phase II project in January 2010.

8. Appendix: Attached Papers

T. Andrew Yang and Dinesh Reddy Gudibandi, "Teaching Wireless Sensor Networks by Incorporating Reorganization Algorithms into the Labs". Journal of Computing Science in Colleges, 23(4). Consortium for Computing Sciences in Colleges. April 2008. pp. 80-88.

T. Andrew Yang, Deepesh Jain, and Bo Sun, “Development of emulation-based projects for teaching wireless sensor networks”. Journal of Computing Sciences in Colleges, 24(2). Consortium for Computing Sciences in Colleges. Dec. 2008. pp. 64-71.

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