Sun SPOT Development Kits for Curriculum Development

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1. Introduction

The goal of this project is to foster more hands-on experience with wireless sensor networks for our students who will gain through this activity a better understanding of sensors and sensor networks. This proposal discusses the course syllabus modifications, the outlines of new course projects and lab exercises that we are planning to offer using Sun SPOTs. This proposal also provides the timeline of the project, our biographies, and the number of Sun SPOT kits requested for the project.

The faculty of the Department of Computer Science at RIT have conducted sensor networks research for a few years. We have a dozen of old MICA2 and six Telos v. B motes produced by Crossbow Inc. Although we started promoting our research results into an educational activity, we believe that we need to acquire more knowledge about a Java based platform as Java is used as a primary programming language in our educational program. Our introductory course sequence (CS1-CS3) is delivered to computer science, computer and software engineering students with more than 500 freshmen enrolled each year.

2. New educational material description

We are planning to introduce the kits requested into teaching of three courses representing networking and artificial intelligence sections of the curriculum. We will develop new educational materials including laboratory exercises and course projects. The kits will also be applied in Master's project and thesis work.

2.1 Laboratory Exercises for the "Ad Hoc Networks" Course

Course topics: Fundamentals of ad hoc networks; collaborative applications; routing and transport algorithms; security; location awareness; energy awareness; sensor networks.
Textbook: Stefano Basagni, Marco Conti, Silvia Giordano, and Ivan Stojmenovic. Mobile Ad Hoc Networking. John Wiley & Sons, 2004. ISBN 0-471-37313-3.
Course web site: http://www.cs.rit.edu/~ark/543/
One section offered per year, 15-20 students per year.

The purpose of the laboratory exercises is to give the students hands-on experience with the ad hoc routing concepts covered in the lectures. For each laboratory exercise, students work in pairs. Each student team has a workstation, a Sun SPOT base station node, and two Sun SPOT sensor nodes. Each team writes a short program and tests it on their own nodes. During the latter part of the exercise, the teams test their programs' interoperability by running their programs at the same time and communicating among all the teams' Sun SPOT nodes.

Exercise 1. Write a class that broadcasts a message to all one-hop-away nodes.
Write a demo program using that class to broadcast a message whenever one of the Sun SPOT buttons is pressed.

Exercise 2. Using the class from Exercise 1, write a class that floods a message to all nodes reachable via one or more hops. Write a demo program using that class to flood a message whenever one of the Sun SPOT buttons is pressed.
Exercise 3. Using the class from Exercise 2, write a class that floods a route discovery message to all nodes, to find a path from a given source node to a given destination node. When the route discovery message reaches the destination node, the message contains the sequence of nodes encountered along the path.
Exercise 4. Using the class from Exercise 3, write a class that floods a route discovery message, then floods a route reply message back. The route reply message contains the path that was discovered from the original source node to the original destination node.
Exercise 5. Write a class that sends a message to a given one-hop-away destination node. Write a program using that class to receive a message and forward the message to a destination node given in the message header.
Exercise 6. Using the classes from Exercises 4 and 5, write a program that discovers a route from the current node to a given destination node and sends a message to the destination along the discovered route. This is a simplified implementation of the Dynamic Source Routing (DSR) ad hoc routing protocol.

2.2 A Term Project for the "Advanced Computer Networks" Course

Course topics: Internet architecture; peer-to-peer overlay networks; network security; wireless networks; routing; congestion control.
Textbook: No textbook required.
Course web site: http://www.cs.rit.edu/~jmk/advnet/
One section offered per year, up to 40 students per year.

Project Title: Developing symmetric key infrastructures using Sun SPOTs

Sensors are useful for applications that require constant monitoring, tracking, and data collection in hostile environments. A sensor node, however, usually has limited processing capabilities powered by small battery. As sensor nodes collect data, they form sensor networks and communicate with other sensors in the neighborhood to analyze the collected data. Since sensor networks are often deployed in hostile environments, sensors can easily be targets of malicious attacks.

How can we secure sensor networks in presence of such attacks? Since sensors have only limited processing power and energy resources, public key agreement schemes such as Diffie-Hellman are irrelevant for securing sensor networks. Since sensor networks are in essence not a trusted infrastructure, using a trusted server such as Kerberos is also not a suitable scheme for security. In contrast, a key-predistribution scheme is considered appropriate for sensor networks since it distributes keys to nodes in the same neighborhood a priori before actual deployment.

In this project, you will develop three different symmetric key pre-distribution systems to secure wireless sensor networks. In the first approach, all the nodes share a group secret key and use that shared group key to encrypt and decrypt messages. The major weakness of this approach is, however, that if one node is compromised, the security of the entire system is in jeopardy.

In the second approach as another extreme case, each node carries the keys for all the other nodes when it is deployed. This approach is certainly more resilient to node compromise than the first because one compromised node would not reveal the keys of any other nodes. The second approach, however, entails additional complexity to carry the keys of other nodes. With limited resources in sensor networks, this is particularly undesirable. Adding a new node is, also, problematic because distributing the key of the new node to other existing nodes is not easy.

The third approach utilizes a random key pre-distribution algorithm with multiple key spaces where two neighboring nodes can determine their secret key after deployment. Each node chooses a set of key spaces prior to deployment, and then computes a shared secret key with its neighbor using Blom's scheme only if they share at least one key space. If two nodes share no common key space, they can still be connected indirectly via their neighbors that indeed form a connected component on the network. More details can be found in R. Blom, "*An Optimal Class of Symmetric Key Generation Systems*," Advances in Cryptography: Proceedings of EUROCRYPT 84, and W. Du, J. Deng, Y. S. Han, P. Varshney, J. Katz, and A. Khalili, "*A Pairwise Key Pre-distribution Scheme for Wireless Sensor Networks*," in the ACM Transactions on Information and System Security (TISSEC), volume 8, issue 2, pages 288-258.

Using your implementations, you are to evaluate the performances of these three different approaches, and compare the results to understand their strengths and weaknesses. To analyze the security, you will measure the percentage of compromised communication links when an adversary captures a portion of the network. You will also measure the communication and computational overheads incurred by these approaches.

2.3 Course Projects for the "Artificial Intelligence" Course

We run five sections per year with 30-40 students per section.

Project No. 1: Expert system for building heating/lighting intelligent control

The project will develop and implement a software technological system based on sensor networks application, which will include an application software realizing a unique control strategy. Such a control strategy would integrate occupants' preferences, the knowledge of their immediate indoor environment and the operation goals, in terms of reduction in energy usage. The monitoring and decision making software will:

- gather information about the immediate indoor environment of the occupants by measuring temperature, humidity and illumination and communicating these data to the central processing unit, executing an intelligent decision making software;
- identify the preferences of individual occupants in indoor environments continuously, as preferences change over time and with the location in the building;
- optimize the trade-off between meeting occupants' preferences and reducing energy usage by introducing optimization rules and providing recommendations on changing the behavior patterns.

As an additional important benefit the software will identify emergency situations such as fire, explosion issue and deliver alarm messages to the occupants and authorities.

Project No.2: Neural networks for signal change detection in sensor networks

An important feature of sensor networks applications is an exciting opportunity to make decisions based on an association of the signals delivered by the network to an aggregate node. (See L. Reznik, G. Von Pless, T. Al Karim, "*Embedding Intelligent Sensor Signal Change Detection into Sensor Network Protocols*", 2005 Second Annual IEEE Communications Society Conference on Sensor and AdHoc Communications and Networks, Santa Clara, 26-29 September 2005, IEEE, pp. 207-217, ISBN 0-7803-9012-1 for more information).

This technological achievement is supposed to produce gain in efficiency of sensor networks applications. In this project you have to design and implement neural network software which should facilitate an efficient and reliable detection of change in temperature and illumination levels.

3. Timeline

Winter 2007-08	Development of lab exercises for Ad Hoc Networks
Spring 2007-08	Teach the lab exercises for Ad Hoc Networks in classroom
Summer 2007-08	Development of projects for Advanced Computer Networks and Artificial Intelligence, Revision of the Ad Hoc Networks labs
Fall 2008-09	Teach the projects developed or revised in the summer
Winter 2008-09	Teach the projects developed or revised in the summer and fall

4. Biography

In his 30 years of industrial and academic computing experience, Alan Kaminsky has developed telephone switching system software at Bell Laboratories, developed real-time embedded control software and fuzzy genetic algorithms at Harris Corporation, taught graduate software engineering as an Assistant Professor at the Rochester Institute of Technology, and worked on printer system architectures at Xerox Corporation. While at Xerox, Alan got involved with Sun Microsystems' Jini Network Technology, led the Jini Printing Working Group industry consortium that defined a draft specification for the Jini Print Service, and was part of the expert group that developed the Java Print Service API released as package javax.print in the standard Java platform. Alan was also one of the original members of the Jini Community Technical Oversight Committee. Now an Associate Professor in the Department of Computer Science at the Rochester Institute of Technology, Alan teaches and conducts research in parallel programming, distributed systems, cryptography, security, small mobile wireless devices, wireless networking, and ad hoc networking. Alan invented Parallel Java (PJ), an API and middleware for parallel programming in 100% Java on shared memory multiprocessor (SMP) parallel computers, cluster parallel computers, and hybrid SMP cluster parallel computers. Alan also invented the Tuple Board, a new paradigm and middleware for distributed collaborative applications running on ad hoc networks of mobile wireless computing devices. Alan has a B.S. in Electrical Engineering from Lehigh University and an M.S. in Computer Engineering from the University of Michigan.

Leon Reznik is a Professor of Computer Science at the Rochester Institute of Technology, New York. He received his BS/MS degree in Computer Control Systems in 1978 and a PhD degree in 1983. Prof. Dr. Reznik is an author of the textbook “Fuzzy Controllers” (Elsevier-Butterworth-Heinemann, Oxford, 1997) and an editor of “Fuzzy System Design: Social and Engineering Applications” (Physica Verlag, 1998), “Soft Computing in Measurement and Information Acquisition” (Springer, 2003), “Advancing Computing and Information Sciences” (Cary Graphic Arts Press, 2005). Dr. Reznik’s research concentrates on study and development of fuzzy and soft computing systems for control, power engineering and computer networks. He has pioneered a new direction where he is applying fuzzy and soft computing models to describe measurement results with applications in sensor networks.

Minseok Kwon is an Assistant Professor in the Department of Computer Science at Rochester Institute of Technology. He received his Ph.D. degree in Computer Science from Purdue University in 2004. His main research interests are peer-to-peer overlay networks, network security, and wireless mobile networks. He has co-authored dozens of papers published in international journals and conferences including IEEE/ACM Transactions on

Networking, Computer Networks Journal, IEEE ICNP, ACM NOSSDAV, and IEEE ICCCN. He has served on many organizing and technical program committees including IEEE Infocom, IEEE Broadnets, IEEE ICCCN, and IEEE Globecom. Since he joined RIT in 2004, he has designed and taught several networking courses, operating systems, and introductory programming courses. He has also supervised over a dozen graduate students toward their M.S. thesis or projects. He has also chosen to participate in the learning community program at RIT that aims at a closely-knit community that helps the academic success of first-year students. Dr. Kwon recently received the Faculty Evaluation And Development (FEAD) grant from RIT twice.

5. Number of classroom kits requested

We would like to request 10 Sun SPOT Java Developer Kits.

6. Facilities

The kits will be place in the Data Management lab, which has an area of approximately 500 square feet with 12 conventional monitors and workstations. It will be available for laboratory exercises and student course work.

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