Analysis of Wireless and Mobile Computer Networks Courses

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Abstract

This paper presents an analysis of wireless and mobile computer networks courses. The results are based on information collected from course Web sites of universities and colleges in computer science, electrical engineering and information science departments. The data analyzed include course titles, course structure, textbooks, major topics and their presentation, projects, and laboratory exercises. We found that wireless and mobile computer network education can be divided into three categories: courses that cover wireless network topics such as computer networks and data-and- communication; courses dedicated to wireless networks; and a sequence of core and supporting courses which typically take the form of a *track*, or a *concentration* in wireless communication.

Introduction

In the late 80's, Mark Weiser and the team at Xerox Palo Alto Research Center (PARC) described the ubiquitous computing research project [14,15]. Two key foundations for achieving the goal of ubiquitous computing are wireless communications and mobile communications. Wireless and mobile communications allow computing devices to "talk" to each other without being constrained by physical cables used in a wired network environment. Recognizing the importance of wireless and mobile communications in today's computing environment, many universities across the world are offering courses on the subject in undergraduate and graduate studies.

Wireless and mobile communication courses are taught either as a part of a degree program typically by a university or college, or as a professional development program offered by an industrial entity or an extension of a college program. Departments that offer such courses include electrical engineering (EE), electrical and computer engineering (ECE), computer science (CS), and information technology (IT). Courses offered by the EE or ECE departments often focus more on communications aspects; those offered by CS departments concentrate more on protocols and their interaction with the Internet; while those offered by the IT departments tend to focus more on security and management of wireless networks.

Since a variety of academic departments with different objectives offer wireless courses, the course topics vary widely. Common topics in EE and ECE courses include radio frequency (RF) circuit design, antennas, modulation techniques, radio communications, cellular telephone systems, wireless signal propagation, signal coding, and other wireless network infrastructure related topics. These topics typically belong to the physical layer when a layered architecture reference framework is used. On the other hand, topics found in the CS courses emphasize

protocols and their interactions with Internet at the data link and network layers. These topics include protocols such as CSMA/CA, Bluetooth, cellular Internet access, mobile IP and other wireless routing issues, as well as the impact of these wireless protocols on the higher layer protocols. Topics discussed in IT courses include wireless network management and security issues.

We begin by briefly discussing major concepts in wireless and mobile communications and then discuss course structures and the topics covered and their presentation. In addition, we present and analyze the textbooks used, hands-on exercises including projects and laboratory exercises.

The analysis will help us reflect on the design of wireless education in both the electrical engineering and the computer science departments. We believe this information will be useful to our colleagues in other universities and colleges as well.

Wireless Communications and Mobile Computing

Forman and Zahorjan [3] stated "*Mobile computing – the use of a portable computer capable of wireless communication – will very likely revolutionize the way we use computers*." Mobile computing requires the support of wireless communication networks. Wireless networks communicate by modulated radio frequency (RF) or infra-red light (IR) and are connected to wired network infrastructures by stationary transceivers, or base stations. The area covered by an individual transceiver's signal is known as a *cell*. When a mobile computing device travels from one cell to another, information needs to be handed over from one cell to another. The hand-over should be smooth so that the user of these mobile computing devices will not notice the cross-cell boundary. Wireless communications is more difficult than wired communications. For example, the surrounding environment interacts with the signal, blocking signal paths and introducing noise and echoes. As a result, wireless communication is characterized by lower bandwidths, higher error rates, and more frequent spurious disconnections when compared to its wired counterpart.

While wireless communication can be mobile or stationary, it is a required building component of mobile computing. In addition, they rely on infrastructure or they can be ad hoc. According to Forman [3], mobility is the *ability to change locations while connected to the network*. Mobility introduces several challenges for network infrastructures. A mobile computer's network address changes dynamically, its current location affects configuration parameters as well as answers to user queries, and the communication path grows as it wanders away from a nearby server. In ad hoc networks, mobility introduces additional challenges in that the network needs to detect link or node failures and update routing information accordingly.

Because of the close relationship between mobile computing and wireless communications, the two topics are often taught in the same course. In the next section, we will examine how these topics are covered in the courses we surveyed.

Course Structures and Topics

Wireless communication and mobile computing topics are found in three different types of courses, those that offer a dedicated course about the subject, those that cover the subject as a part of a course, and those that study the subject in a sequence of courses that form a *track* or a *concentration*. From the data we collected, the most popular choice is to have a specialized

course. Such a course typically requires an introductory computer network course as background. Courses are offered at the undergraduate senior or introductory graduate level. We collected information on 27 courses (17 unique titles) in this category from 20 universities. Common course titles include "Wireless communications", "Wireless networking", "Mobile computing and wireless networking", and "Mobile networking." See a list of schools in Appendix A and a list of course titles in Appendix B. The contents of these courses have two different flavors, one from the EE point of view, covering more communications topics, and the other from the CS point of view, dealing with more layered protocols. There is a sizable overlap of the topics in EE and CS courses. Major topics in EE courses include antennas, signal propagation, encoding, spread spectrum, coding and error control. Topics common in both the EE and the CS courses include Media Access Control (MAC) protocols such as TDMA, FDMA, CDMA and others, cellular networks, the IEEE 802.11 sequence, and WAP. Topics appearing in mostly CS courses include mobile IP, ad hoc networks, mobile network routing, TCP for mobile networks, Bluetooth, and various application protocols.

Instead of a complete course on the subject, many universities present the contents of wireless network and mobile computing as a part of another course, typically a computer networks course. In this setting, wireless communications and mobile computing are discussed in a chapter or a few sections. The most common coverage is the IEEE 802.11 protocol family. Many general computer networks textbooks contain such a chapter or sections. Examples of these textbooks include those by Kurose [4], Peterson [7], and Tanenbaum [11]. A discussion of textbooks will follow this section.

A less popular but notable option is to offer a track or a concentration in wireless communication and mobile computing, or computer networks in general with a component in wireless communication and mobile computing. In this context, we will use the word *track* and *concentration* interchangeably. A track consists of a number of courses related to the subject of wireless communication and mobile computing. It is typically offered at a graduate (master's degree) level. We found that relatively few universities have such a track. One example is the University of Colorado – Boulder, which has a "Wireless System Master of Science Track" [2]. The track requires students to take one course from each of the five core areas plus some electives. The courses are chosen from different disciplines. The five core areas are *Standards and Regulatory Landscape, Wireless Systems, Networking, Software,* and a *Focus Course*. The elective courses come from different topic areas as well. They include wireless systems, telecom economics, telephone networking, information theory, and network security. Students also have the option to work on a thesis which typically requires "close interaction with a faculty advisor over two or three semesters" [2].

Textbooks

A total of 20 textbooks were found in the courses surveyed. See Appendix C for a complete list of the titles. Appendix D is a cross reference of universities, course titles, and textbooks. Here we will examine these books from two perspectives, one is to categorize the books for EE and CS students; the other is to examine common topics of the books. The books on wireless and mobile communications usually target two groups of students, electrical engineering and computer science. Books used by electrical engineering students often contain more communication theory. Representatives of these books include those by Stallings [10], Rappaport [8], and Schiller [9]. Books used more often by computer science departments include those by Kurose [4], Perkins [5,6] and Basagni [1]. Topics common to both departments

include the IEEE 802.11 protocols, TCP/IP, mobile IP, and the Bluetooth protocol. Topics leaning more towards electrical engineering students include communications theory, telecommunications, RF circuit design, radio communications, satellite communications, signal coding, spread spectrum, and antennas and propagation. The computer science flavored textbooks often contain topics ranging from routing protocols such as dynamic source routing, link-reversal routing, link-stage routing, zone routing and others, DHCP, to application protocols and computer network security.

Hands-on Experiences

We found relatively few hands-on experiences in wireless and mobile communication or networks courses. Most of these courses use traditional homework or research papers for assignments.

An example of a wireless programming project involves implementing the IEEE 802.11 protocol on top of a Cybiko interface [13]. Students implement a simplified version of the 802.11 MAC layer on the Cybiko. They are asked to extend the services of the RF physical layer, and implement a set of services to be provided to the layer above it. Students do not have a base station or distribution system and assume that all computers are in the same cell. In addition, to make the project manageable, students are not concerned with power management or wireless encryption protocols [13].

Another example is from the University of California – Santa Barbara Mobile Computing course. In this project students implement an application on top of the Hewlett Packard pocket PC iPAQ. Suggested applications include streaming video, ad hoc network, uni-directional links, and application developments [12].

Summary

Widespread use of mobile and wireless technologies has led to new course offerings in this growing area. We surveyed wireless and mobile communication courses using information collected from the web. We found that course contents, textbooks, topics covered, and hands-on experiences vary greatly from course to course. We examined the course structures, topics covered and their presentation, textbooks used, and two hands-on projects that are available from the Web.

References

1. S. Basagni, M. Conti, S. Giordano and I. Stojmenovic, (editors), *Ad Hoc Networking*, Wiley, August 2004.
2. Colorado, Boulder, Wireless Systems Master of Science Track http://ece-www.colorado.edu/~timxb/wirelesstrack.html
3. G.H. Forman and J. Zahorjan, "The Challenges of Mobile Computing", *IEEE Computer*, 27(6), April 1994, 38-47.
4. J. F. Kurose and K. W. Ross, *Computer Networking – A Top-Down Approach Featuring the Internet*, Addison-Wesley Publishing, 3rd edition, 2005.
5. C. Perkins, *Mobile IP: Design Principles and Practices*, Addison-Wesley, 1998.

6. C. Perkins, *Ad hoc Networking*, (Editor), Addison-Wesley, 2000.

7. L. L. Peterson and B. S. Davie, *Computer Networks – A Systems Approach*, Morgan Kaufmann Publishing, 3rd edition, 2003.

8. T.S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd edition, Prentice Hall, 2002.

9. J. Schiller, *Mobile Communications*, 2nd edition, Addison-Wesley, 2003.

10. W. Stalling, *Wireless Communications and Networks*, Pearson Education, November 2004.

11. A.S. Tanenbaum, *Computer Networks*, 4th edition, Prentice Hall Publishing, 2003.

12. UCSB Mobile Computing course project, Winter 2004, http://www.cs.ucsb.edu/~ebelding/courses/284/w04/index.html

13. Vassar College, 802.11 Implementation Project http://www.cs.vassar.edu/~cs395/Project/project.html

14. M. Weiser, "The Computer for the Twenty-First Century", *Scientific American,* September 1991, 94-104.

15. M. Weiser, "Some Computer Science Issues in Ubiquitous Computing", *Communications of the ACM*, vol 36, no 7, July 1993, 75-84.

Appendix A: List of Colleges and Universities

1. Arizona State University
2. Bucknell University
3. Carnegie Melon University
4. Columbia University
5. Eastern Michigan University
6. Georgia Tech
7. Johns Hopkins University
8. Penn
9. Rose-Hulman Institute
10. Rensselaer Polytechnic Institute
11. Southern Methodist University
12. Stanford
13. University of Alabama -- Birmingham
14. University of Akron
15. University of Guelph
16. University of California – Berkeley
17. University of California – Davis
18. University of California – Santa Barbara
19. University of Illinois – Urbana-Champaign
20. Vassar College

Appendix B: List of unique course titles

1. Advanced Topics in Wireless Communications
2. Advanced Topics in Wireless Networks
3. Advanced Wireless Communications Networks
4. Introduction To Personal Wireless Communication
5. Mobile and Wireless Networks
6. Mobile Computing
7. Mobile Networking
8. Mobile Wireless Networks
9. Special Topics: Mobile and Wireless Networks
10. Special topics: Mobile Computing and Wireless Networking
11. Topics in Wireless System Design

12. Wireless and Mobile Networking
13. Wireless Communications
14. Wireless Local Area Networks
15. Wireless Networking
16. Wireless Networks
17. Wireless Systems

Appendix C: List of textbooks

1. *Wireless Communications and Networks*, William Stallings, Pearson Education, November 2004.
2. *Wireless Communications: Principles and Practice*, Theodore .S. Rappaport, 2nd edition, Prentice Hall, 2002.
3. *Mobile Communications*, Jochen Schiller, 2nd edition, Addison-Wesley, 2003.
4. *Ad hoc Networking*, Charles Perkins, (Editor), Addison-Wesley, 2000.
5. *Computer Networking: A Top-Down Approach Featuring the Internet*, James F. Kurose and Keith Ross, Addison-Wesley, 2002. (newer edition available)
6. *The IEEE 802.11 Handbook: A Designer's Companion*, Bob O'Hara and Al Petrick, IEEE Press: New York, 1999.
7. *Wireless Personal Communications Systems*, David Goodman and Andrew J. Viterbi, (Editors), Addison-Wesley, 1997.
8. *Wireless and Personal Communications Systems*, Vijay Garg and Joseph E. Wilkes, Prentice-Hall, 1996.
9. *Mobile Radio Networks: Networking and Protocols*, Bernhard H. Walke, Wiley, 1999.
10. *Wireless Information Networks*, Keveh Pahlavan and Allan H. Levesque, Wiley, 1995.
11. *Second Generation Mobile and Wireless Networks*, Uyless Black, Prentice Hall, 1999.
12. *The Mobile Communications Handbook*, 2nd edition, Jerry D. Gibson, CRC Press, 1999.
13. *Mobile IP: Design Principles and Practices*, Charles E. Perkins, Addison-Wesley, 1998.
14. *High-Speed Wireless ATM and LANs*, Benny Bing, Artech House, 2000.
15. *Wireless and Mobile Network Architectures*, Yi-Bing Lin and Imrich Chlamtac, Wiley & Sons, 2001.
16. *Introduction to Wireless and Mobile Systems*, Dharma Prakash Agrawal and Qing-An Zeng, Brooks/Cole, 2002.
17. *Mobile Ad Hoc Networking*, Stefano Basagni, Marco Conti, Silvia Giordano, and Ivan Stojmenovic (Editors), IEEE/Wiley, 2004.
18. *The Handbook of Wireless Ad hoc Wireless Networks*, Mohammad Ilays, CRC Press, 2002.
19. *High Frequency:Techniques: An Introduction to RF and Microwave Engineering*, Joseph F. White, Wiley and Sons, 2004.
20. *RF and Microwave Wireless Systems*, Kai Chang, Wiley and Sons, 2000.

Appendix D: Cross Reference of Universities, Course Titles, and Textbooks

University	Course title	Textbook(s)
1	16	1
2	11	19, 20
3	12,15	2
4	12	2
5	16	1
6	12	1
7	2	
8	15	
9	17	
10	8	
11	16	2,7,8,9,10,11,12,13,14
12	1,4,13,14,	
13	13	1
14	13	2
15	9	4,16,17,18
16	10	
17	3,5	15
18	6,7	3,4,5
19	15	2
20	16	1