GRADUATE-UNDERGRADUATE INTERACTION IN WIRELESS APPLICATIONS RESEARCH AND DEVELOPMENT

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Abstract *- The School of Electrical and Computer Engineering at Purdue University is offering a new Mobile Communications Project class for junior and senior undergraduate students. Students work in teams to design real-world applications for different mobile communications technologies. The Wireless Application Development group is composed of several teams that aim to develop state-of-the-art wireless applications for IEEE 802.11 based mobile devices. Each of these undergraduate teams in this group is led by a graduate student, under the supervision of the professor. The research and development projects conducted in this group have led to a couple of conference papers and a journal paper in the past semesters. This paper describes the projects done in this group by the undergraduate students, presents the graduate student advisory experience, and the graduate-undergraduate interaction throughout the process, and suggests methods for such interactivity to be productive. It also discusses the impact of such interactions on the undergraduate students as well as on the graduate mentors.*

Index Terms - Undergraduate research experience, wireless applications, graduate-undergraduate interactions, mentoring.

INTRODUCTION

The School of Electrical and Computer Engineering at Purdue University, West Lafayette, is offering a new Mobile Communications Project (ECE 495M) class for junior and senior undergraduate students. This two credit hour class consists of two components: weekly lectures and design and development projects. The weekly lectures cover different aspects of mobile technologies, including mobile applications development, wireless communication systems, system security, and other advanced topics depending on the instructors' interests. In addition to attending these lectures, the students are also required to participate in design and development projects under the supervision of a professor and possibly graduate students. Each student is required to submit a thorough design plan at the beginning of the semester, progress reports during the semester, and a final report by the end of the semester. Students are expected to work closely with the professors and graduate students throughout the semester to come up with real-world applications and designs, and they are also expected to make an oral presentation on their projects at the end of the semester.

The Wireless Application Development group (WAD), which is led by Prof. Catherine Rosenberg, is one of the classes' six groups. The aim of WAD is to develop state-of-the-art wireless applications for IEEE 802.11-based mobile devices. Starting with one undergraduate and one graduate student in the fall of 2001, WAD has since grown to four graduate students and six undergraduate students, with each undergraduate student being mentored by a graduate student. Each graduate-undergraduate team worked on an independent project (some teams had two undergraduate students while others had one). The entire group met once a week with each team giving progress reports and receiving feedback from the professor, while the individual teams met as regularly as was required. The low undergraduate-to-graduate ratio of the teams facilitated excellent interaction, led to more in-depth discussions during the design process, and allowed the undergraduate students to receive the necessary attention from their mentors.

Results of some of WAD's projects over the past few semesters have led to several conference papers [1-3] and a journal paper [4]. Some of the group's designs have also been adopted by the Information Technology at Purdue (ITaP) unit for deployment throughout the campus. Descriptions of the projects will be given in the later sections.

This paper is organized as follows. We present some highlights of the projects by WAD in the next section to demonstrate the level of research that undergraduate students were able to conduct. We then describe the undergraduate-graduate student relationships and the impact on both the mentors and the mentored. Finally, we propose suggestions for the adaptation of this model to other engineering projects.

PROJECT HIGHLIGHTS

WAD has had a tradition of projects that result in deployable mobile device applications. We present Location Discovery Service (LODS) [1, 4] and Remote Printing Service (RPS) [2] which have received the most attention, and also describe two other notable projects which are E-Classroom [3], and E-Stadium.

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Location Discovery Service (LODS)

LODS [1, 4] is a Web service that allows mobile users, using Personal Digital Assistants (PDAs) or laptops, on an IEEE 802.11 wireless LAN to find out their approximate location within a campus or an enterprise. It also allows location-based applications to detect a user's location and suggest the nearest points of interest, e.g., printers, elevators, and vending machines. Started in fall 2001, this is expected to highly enhance the experience of mobile hosts within a campus or an enterprise. A major advantage of the service is that it is easy to deploy and does not require large infrastructure investment. LODS is especially useful in a campus or an enterprise environment when a mobile user needs to find the closest printer, computing lab, elevator, cafeteria, etc. In addition, the service is accessible directly by common Web browsers so virtually all mobile hosts can use it without purchasing additional hardware (i.e., a GPS receiver) or software. LODS can also be used in metropolitan setting with wireless network connectivity, like the wireless coffeehouse. Currently the design of LODS has been adopted by ITaP for testing and is under the first phase of deployment. LODS is expected to be in service at Purdue University, West Lafayette campus, which has a population of 35,000 users, in the near future.

This project required a working knowledge of UNIX shell scripting, network programming, and wireless network standards. Working on the project allowed the students to significantly improve on these skills while improving their understanding of wireless technology in general.

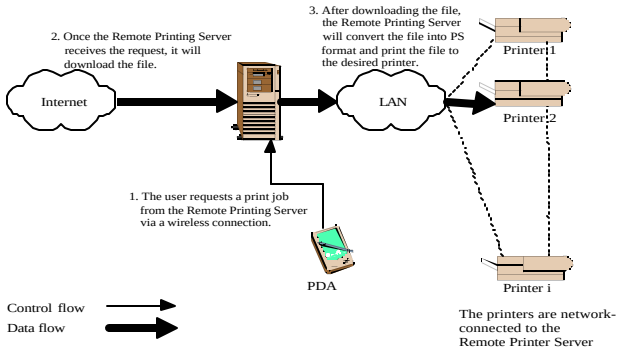

FIGURE 1
REMOTE PRINTING SERVICE

Remote Printing Service (RPS)

RPS [2] is another of WAD's projects that has been adopted for deployment by ITaP and has also led to several conference publications. It is a Web-based printing service for PDAs and laptops that enables their users to print virtually any document that can be accessed through a Web browser (i.e., HTML, PS, PDF, and almost all types of images) using any printer connected to the network without downloading the document. The advantages of this service are that the need for a printer driver on the mobile device is eliminated, and that files that may not be viewable on the PDA, as it might be lacking the appropriate software, can still be printed. In addition since the mobile devices do not need to download large files before printing them, power and memory consumption are reduced. A brief overview of RPS is presented in Figure 1.

This project gave students a better understanding of database management, network programming, and printing technologies.

E-Classroom

This project began in the fall of 2002 in an attempt to come up with designs that would make the Purdue Air Link (PAL) network a secure enough network to allow for the development and deployment of E-learning applications. Research has shown that both students and instructors have a lot to gain from the introduction of wireless devices to the classroom. While there has been a lot of work in the development of E-learning applications, little to no attention had been given to the design of a secure and easily adaptable underlying network necessary for running such applications. We have designed mechanisms which when added to the PAL network will allow instructors to maintain control of the classroom, and prevent students from taking advantage of the technology to cheat or skip classes. In addition, our mechanisms make PAL a flexible network enabling it to support various kinds of wireless classroom environments needed for the classes taught at Purdue University.

Students working on this project got an opportunity to learn about wireless network architecture, security, and standards.

E-Stadium

The E-stadium project aims at enhancing the stadium experiences of wireless device (such as cell-phones and PDAs) owners while they watch football or basketball games. Our goal is to design services such as sports trivia, real-time polling, sports tickers (showing real-time scores for games that are played at the same time), find-a-friend in the stadium, and instant messaging. An ongoing project, which began in fall 2002, the E-Stadium prototype is expected to be ready in the summer of 2003.

GRADUATE-UNDERGRADUATE INTERACTION

In addition to giving undergraduate students the opportunity to work on exciting new wireless technology, WAD attempts to provide the necessary environment for the students to develop or improve their research skills. To facilitate this, volunteer graduate students were paired with the undergraduate students to form teams with the graduate students serving as both mentors and team leaders. A major key to the success of WAD was that both undergraduate and graduate students chose the projects they worked on. While the professor suggested ideas for projects, the students were strongly encouraged to come up with their own ideas. Each

team of graduate and undergraduate students held independent brainstorming sessions and used the weekly meetings as an opportunity to run their ideas by the professor and the other WAD teams. After the projects were decided and approved by the professor, the teams formalized their ideas in the form of a project proposal and began working in earnest. Each week, every team had an opportunity to update the group on any progress they had made or problems they had encountered. Even though most of the burden of completing the project work was shouldered by the undergraduate students, having the graduate students as a resource made it a lot easier to get tangible work done. It is important to stress that the graduate-undergraduate relationship was not that of a teaching assistant-student relationship where the student asks questions and the teaching assistant just answers them. The graduate students were involved in every aspect of the project making them partners rather than supervisors.

The undergraduates benefited greatly from having a more experienced student on their teams. The early stages of the design process can be very trying, but thanks to their mentors, the students were spared having to spend excessive amounts of time going down avenues that were bound to lead to dead ends. Instead of using the professor as the primary resource as the traditional undergraduate research classes do, our approach used the mentors as the primary resource. This difference cannot be overlooked as it was a major contributor to the success of WAD. Students are able to ask their mentors questions about mundane things which they would probably not ask the professor. For example undergraduate students could ask questions such as: What is the best search engine? Where to find papers and how to get the most out of a paper? The fact the mentors were in the undergraduate students' shoes not too long ago, allows them to relate to the students better than a professor would. Mentors and their students developed friendships which made it even easier for them to communicate.

Instead of feeling lost at the start of the project, the undergraduate students now have access to the tools they needed to succeed. In addition to helping their students avoid common mistakes new researchers make, the mentors taught the students proper design methodology, problem formulation, and how to quickly recognize the feasibility of their ideas. Given that the students felt comfortable with their mentors, they were able to use them as sounding boards for ideas they might otherwise have considered stupid. The mentors encouraged the students to share their "wild" ideas and the students learned the ideas that seemed impossible could be feasible with minor or in some cases no modifications. Another skill that WAD undergraduate students learned was how to properly communicate their ideas to others. The informal weekly meetings provided the students an excellent opportunity to practice giving presentations in a no-pressure situation. The mentors, having more experience in this area, were able to give the students positive feedback on their presentation skills.

The undergraduate-graduate interaction was also beneficial to the graduate students acting as mentors. They were able to gain experience in helping their younger colleagues succeed. Usually having to mentor one (at most two) student ensured that they were not overwhelmed by the experience, but in fact found it to be rewarding. The graduate students encouraged their students when they got frustrated and kept them focused on the goal when they strayed, as is the tendency of new researchers. The mentors improved their problem formulating skills by helping their students refine their ideas. They had an excellent opportunity to improve their communicating skills as they occasionally had to break down abstract ideas for their students. Being responsible for the project gave the graduate students an opportunity to learn how to delegate appropriate amounts of work to their students, set reasonable goals, and keep to a schedule while producing results. These are skills that will be useful to the mentors regardless of whether they pursue careers in academia or industry.

The timely completion of projects undertaken with undergraduate-graduate interaction in addition to the satisfaction derived from this interaction by both groups of students have prompted us to suggest this model for more Engineering projects. The model does not need to apply only to undergraduate and graduate students, but could simply involve pairing up a less experienced researcher with a more experienced one acting as a mentor. It is obvious that the more involved the mentor is with the project, the faster it will be completed, however the level of involvement need not be as high as it was in WAD. Providing mentors for new graduate students is an example of such a situation.

While our experience with mentoring was highly successful within WAD, here are some suggestions that could make applying this model to other engineering projects a little easier.

- The undergraduate students struggled with problem formulation, but did well solving well-defined problems. We suggest that in the beginning, mentors help by breaking down the project into specific tasks their students can accomplish and slowly help them figure out how to do the breaking down.
- Undergraduate students should take notes at every meeting, drastically reducing their chances of forgetting relevant information. Students learn that ideas might not be useful at the time they are generated, but could be useful down the road.
- Undergraduate students should be encouraged to run the meetings. It is important not to lose sight of the fact that the projects belong to them even though the mentors are ultimately responsible. Mentors should never make their students feel like they are following orders instead they should feel like equal partners, if not leaders, on the team.
- Mentors should be prepared to dedicate time to their students and treat their ideas seriously. The students develop a level of trust by sharing their 'wild" ideas

with their mentors. Spending the time to consider the feasibility of the ideas not only increases the confidence of the students, but also helps improve the mentor's skills.

- Brainstorming sessions involving only the student and mentor were helpful in building the trust between the two students. The undergraduate students realized that their ideas were as good as or better than those of their mentors. Both parties learned to listen to and learn from each other's opinions. Having gained confidence brainstorming with their mentors, the undergraduate students were not hesitant to contribute when WAD brainstormed as a group.

CONCLUSION

We have described the experiences of the undergraduate and graduate students in the WAD group where each undergraduate student is mentored by a graduate student. Our experience has shown that both groups of students benefited tremendously from this partnership. This has allowed undergraduate students to conduct research they might not have been able to do on their own. Many of the projects resulting from this partnership have led to conference and journal papers as well as deployment on actual networks. Undergraduate students learned proper research methodology and how to avoid common mistakes new researchers make; improved their presentation and brainstorming skills, and gained confidence in their own ideas. Mentors got an opportunity to improve their communication and problem formulation skills, and learned how to manage and take responsibility for a project. We also made suggestions that should ease applying our approach to similar engineering projects.

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