

An Overview of an Integrated Research and Graduate Education Program in Advanced Networking

Scott F. Midkiff
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061 USA

Abstract

This paper discusses the Integrated Research and Education in Advanced Networking (IREAN) program being created at Virginia Tech. The IREAN program is an experiment in graduate education that seeks to significantly improve the quality of Ph.D. graduates in the networking area by moving away from the single-discipline, narrow-focus, lone-researcher model of traditional Ph.D. programs. The program integrates multiple disciplines through the participation of faculty and students from three colleges and through collaborative multidisciplinary research projects. The program also integrates research with education experiences and integrates research and technical education with training in “soft skills,” including communications and teamwork. This paper describes the program’s goals and the educational program, implementation strategies to be used to achieve these goals, and the program’s curriculum.

I. Introduction

With a five-year Integrative Graduate Education and Research Training (IGERT) grant awarded by the National Science Foundation (NSF) in August 2000, Virginia Tech is creating the Integrated Research and Education in Advanced Networking program. This program is presently in a one-year “start-up” phase and will be fully operational in Fall 2001. The IREAN program enables faculty and Ph.D. students from computer engineering, electrical engineering, computer science, industrial and systems engineering, economics, and business to work on multidisciplinary research targeted at a vision of the future Internet as the common, ubiquitous and global communications infrastructure. The program’s research thrusts are broadband wireless access, mobile access to Internet resources and applications, Internet appliances, quality of service, heterogeneous network security, and management of large-scale networks. Of equal importance and of, potentially, greater long-term impact, the IREAN program seeks to expand the traditional model of graduate education to produce Ph.D. graduates in advanced networking who are prepared to meet the future challenges of industry, government, and academia.

II. Program Goals

The program seeks to produce students with the following attributes.

- Strong research ability and in-depth knowledge in an aspect of advanced networking.
- Ability to integrate technical, business, regulatory, and global issues.
- Ability to work effectively in distributed, culturally diverse, multidisciplinary teams.
- Ability to communicate effectively and to be effective teachers as well as learners.

- Ability to cope with ethical dilemmas and conduct themselves in an ethical and professional manner.

In addition, the program seeks to increase and enhance the involvement of women and underrepresented minorities in the networking and general information technology areas and to provide educational benefits to undergraduate and masters students in the participating academic departments. Multiple implementation strategies are being applied.

- Creating a research program focused on overcoming barriers to achieving a vision of the future Internet.
- Integrating research with “real world” problems through partnerships with industry, university-based infrastructure projects, and other universities.
- Revising existing and creating new for-credit courses and non-credit seminars.
- Aggressive recruiting to establish a culturally diverse group of participants.
- Including student participants in special teaching and mentoring programs.
- Hosting visits of international students and scholars and providing international internship opportunities for student participants.

III. Educational Program and Desired Outcomes

The fundamental purpose of the IREAN program is to implement a unique research and educational environment to create Ph.D. students superbly prepared to face today’s and tomorrow’s challenges in industry, government, and academia. The program will engage Ph.D. students, known as IREAN Fellows, from electrical engineering, computer engineering, computer science, industrial and systems engineering, economics, and business in a variety of ways as they progress through the IREAN program at Virginia Tech.

The traditional Ph.D. degree program, which focuses almost completely on developing technical expertise in a relatively narrow field of knowledge, does not prepare students for the contemporary multidisciplinary, team-oriented environment that is critical to success in academia, government, and industry. Today, and even more so in the future, researchers must be able to work in multidisciplinary teams that are often geographically distributed and culturally diverse, consider global, economic, and regulatory factors in their research, and communicate effectively in a variety of settings. The objective of our education and training program is to produce Ph.D. graduates who will become highly productive researchers prepared to meet the new challenges in advanced networking. Specifically, we plan to educate and train highly qualified to ensure the following five student outcomes (A through E).

- A. Graduates from the program should have strong research abilities and in-depth knowledge in some aspect of advanced networking.
- B. Graduates should understand and be able to integrate technical, business, regulatory, and global issues in the creation and analysis of technologies, systems, algorithms, protocols, and applications.

- C. Graduates should be able to work effectively in distributed, culturally diverse, multidisciplinary teams.
- D. Graduates should be able to communicate effectively with both subject area experts and the layperson and be effective as teachers as well as learners.
- E. Graduates should be able to successfully cope with ethical dilemmas and conduct themselves in an ethical and professional manner.

In addition to the desired student outcomes listed above, we have two additional outcomes (F and G) for the overall program.

- F. The program should increase and enhance the involvement of women and underrepresented minorities in the networking and general information technology areas.
- G. The program should provide educational benefits to undergraduate and masters students in the participating academic departments.

IV. Strategies

The following six strategies will be applied to provide the education and training needed to produce the five outcomes (A through E) in our Ph.D. students and to achieve the two additional desired program outcomes (F and G). Implementation approaches for each are discussed.

1. We are developing a research program that addresses key problems in advanced networking. The research program will engage IREAN Fellows and other students in research related to the future Internet.

This program is being implemented initially by extending existing multidisciplinary research in networking, wireless communications, and business. For example, Virginia Tech's Center for Wireless Communications includes participants from the Department of Electrical and Computer Engineering, the College of Business, and other units. Faculty and students are already collaborating on research in cost-effective broadband wireless technologies that considers both technical issues, such as modems, radio frequency circuit design, and adaptive network protocols, and business issues, such as siting, deployment, and pricing.

2. We are integrating our research with "real world" problems through partnerships with industry, university-based infrastructure projects, and other universities. These partnerships will provide internships for IREAN Fellows and collaborative research projects.

We will both build on existing and develop new relationships and projects. For example, Virginia Tech is a partner in the Internet Technology Innovation Center (TIC). The Internet TIC focuses on providing university research and expertise to assist companies and government in deploying and leveraging networking and other information technologies. The university is also involved with infrastructure deployment projects in rural Virginia. All

of these endeavors involve students and provide important exposure to real problems in real environments.

3. We are enhancing existing and creating new for-credit courses and non-credit technical and professional seminars for IREAN Fellows and other students.

We are developing two multidisciplinary courses, in addition to two new networking courses already taught in 1999-2000. We will integrate a writing course for graduate students and a communications workshop into our education and training program. We have begun a new IREAN Seminar Series that will address ethics, and professional development, as well as technical, business, and policy issues. The curriculum is discussed further in Section V.

4. We are striving to recruit a culturally diverse group of IREAN Fellows, with emphasis on involving women and underrepresented minorities in the program.

Recruiting students to a Ph.D. program is a difficult task. It is especially difficult in the networking area where employment demand is strong and will likely continue to be strong. We are emphasizing personal contact and “getting the word out” through student conferences and other meetings. We have evidence that some students are attracted by the broader experience offered by the IREAN program versus a traditional Ph.D. program.

5. We will involve IREAN Fellows in special teaching opportunities to improve their teaching and communication abilities and to benefit other participants. IREAN Fellows will serve as teachers and mentors in a special summer research program for undergraduate students.

Specific plans for this program are yet to be developed. However, there are existing programs for undergraduates and we can integrate with these. In addition, the NSF’s Research Experiences for Undergraduates (REU) program is a potential source of funding to support such a program.

6. We will provide IREAN Fellows with international experiences by sponsoring visiting international students and scholars. We will also offer international internship opportunities to IREAN Fellows.

Virginia Tech, and especially the College of Business and the Department of Electrical and Computer Engineering, currently have strong relationships with universities in Germany, France, and Switzerland that can offer interesting experiences for our students. For example, Virginia Tech graduate students have gone to France to take courses and complete internships in French research laboratories. There is also promising discussion of an international simulation experience in the policy area that would involve IREAN Fellows and other students.

Table 1 indicates the relation between outcomes, as discussed in Section III, and the six strategies discussed above. A check mark in the table indicates that a given strategy supports, at least to some extent, a particular outcome.

Table 1. Relationship Between Strategies and Outcomes

Student and Program Outcomes	Implementation Strategies					
	1. Research program	2. Partnerships/internships	3. Courses and seminars	4. Recruitment program	5. Teaching program	6. International program
A. Strong research capability and in-depth technical knowledge	✓	✓	✓			✓
B. Integrate technical, business, regulatory and global issues	✓	✓	✓		✓	✓
C. Distributed, culturally diverse, multidisciplinary teamwork	✓	✓		✓	✓	✓
D. Effective communicators and effective teachers	✓	✓	✓		✓	
E. Ethical and professional conduct	✓	✓	✓		✓	✓
F. Involve women and underrepresented minorities	✓	✓		✓	✓	
G. Educational opportunities for undergraduates and others	✓	✓	✓		✓	✓

V. Curriculum Issues

The IREAN program is not a new degree program. IREAN Fellows will earn their degrees in existing programs such as Computer Engineering, Industrial and Systems Engineering, and Economics. However, IREAN Fellows will be required to take a small set of common core courses. The proposed set is shown in Table 2. It is believed that these courses will provide the foundation required for participation in multidisciplinary research programs and other activities.

The preparation course, “Fundamentals of Computer Systems,” will be taken by students needing additional technical background for the “Computer Networks” course. The course is an existing foundation course in the Master of Information Technology program and is tailored to prepare students for networking and computer engineering courses. The writing course would be taken by students for whom work beyond the writing seminar is required.

The core traditional technical background will be provided to all students through an existing graduate course, “Computer Networks,” and a choice of a networking elective. The multiple disciplines will be integrated in two other courses. The “Business and Economics of Advanced Networking” course will introduce business issues in the context of networking. The “Simulation and Optimization” course will provide research “tools” for participating students, again in the context of networking.

Table 2. Proposed Set of Core Courses

Preparation	“Fundamentals of Computer Systems”
Networking	“Computer Networks” Networking Elective
Integrative	“Business and Economics of Advanced Networking” “Simulation and Optimization”
Writing	Writing Course

VI. Conclusions

The IREAN program is an experiment in graduate education that will attempt to produce graduates who have a broader understanding of the networking field, including business, policy, and global issues, are effective communicators, can work in teams, and can successfully cope with ethical dilemmas. This experiment involves multiple faculty from multiple programs and an integration of education and research. The program will begin in full force in Fall 2001. We look forward to reporting results based on the program’s evaluation.

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SCOTT F. MIDKIFF

Scott Midkiff is a Professor in the Bradley Department of Electrical and Computer Engineering at Virginia Tech. He teaches courses in computer networks and computer engineering and conducts research in computer networking. He serves as the principal investigator of the IREAN program described in this paper. Midkiff received the Ph.D. in 1985 from Duke University. He is a member of the ASEE, IEEE, and ACM.