AN INTERVIEW WITH…

Deborah Estrin

Deborah Estrin is Professor of Computer Science at UCLA, the Jon Postel Chair in Computer Networks, Director of the Center for Embedded Networked Sensing (CENS), and co-founder of the non-profit openmhealth.org. She received her Ph.D. (1985) in Computer Science from M.I.T., and her B.S. (1980) from UC Berkeley. Estrin's early research focused on the design of network protocols, including multicast and inter-domain routing. In 2002 Estrin founded the NSF-funded Science and Technology Center, CENS (http://cens.ucla.edu), to develop and explore environmental monitoring technologies and applications. Currently Estrin and collaborators are developing **participatory sensing** systems, leveraging the programmability, proximity, and pervasiveness of mobile phones; the primary deployment contexts are mobile health (http://openmhealth.org), community data gathering, and STEM education (http://mobilizingcs.org). Professor Estrin is an elected member of the American Academy of Arts and Sciences (2007) and the National Academy of Engineering (2009). She is a fellow of the IEEE, ACM, and AAAS. She was selected as the first ACM-W Athena Lecturer (2006), awarded the Anita Borg Institute's Women of Vision Award for Innovation (2007), inducted into the WITI hall of fame (2008) and awarded Doctor Honoris Causa from EPFL (2008) and Uppsala University (2011).

Please describe a few of the most exciting projects you have worked on during your career. What were the biggest challenges?

In the mid-90s at USC and ISI, I had the great fortune to work with the likes of Steve Deering, Mark Handley, and Van Jacobson on the design of multicast routing protocols (in particular, PIM). I tried to carry many of the architectural design lessons from multicast into the design of ecological monitoring arrays, where for the first time I really began to take applications and multidisciplinary research seriously. That interest in jointly innovating in the social and technological space is what interests me so much about my latest area of research, mobile health. The challenges in these projects were as diverse as the problem domains, but what they all had in common was the need to keep our eyes open to whether we had the problem definition right as we iterated between design and deployment, prototype and pilot. None of them were problems that could be solved analytically, with simulation or even in constructed laboratory experiments. They all challenged our ability to retain clean architectures in the presence of messy problems and contexts, and they all called for extensive collaboration.

What changes and innovations do you see happening in wireless networks and mobility in the future?

I have never put much faith into predicting the future, but I would say we might see the end of feature phones (i.e., those that are not programmable and are used only for voice and text messaging) as smart phones become more and more powerful and the primary point of Internet access for many. I also think that we will see the continued proliferation of embedded SIMs by which all sorts of devices have the ability to communicate via the cellular network at low data rates.

Where do you see the future of networking and the Internet?

The efforts in named data and software-defined networking will emerge to create a more manageable, evolvable, and richer infrastructure and more generally represent moving the role of architecture higher up in the stack. In the beginnings of the Internet, architecture was layer 4 and below, with applications being more siloed/monolithic, sitting on top. Now data and analytics dominate transport.

What people inspired you professionally?

There are three people who come to mind. First, Dave Clark, the secret sauce and unsung hero of the Internet community. I was lucky to be around in the early days to see him act as the "organizing principle" of the IAB and Internet governance; the priest of rough consensus and running code. Second, Scott Shenker, for his intellectual brilliance, integrity, and persistence. I strive for, but rarely attain, his clarity in defining problems and solutions. He is always the first person I email for advice on matters large and small. Third, my sister Judy Estrin, who had the creativity and courage to spend her career bringing ideas and concepts to market. Without the Judys of the world the Internet technologies would never have transformed our lives.

What are your recommendations for students who want careers in computer science and networking?

First, build a strong foundation in your academic work, balanced with any and every real-world work experience you can get. As you look for a working environment, seek opportunities in problem areas you really care about and with smart teams that you can learn from.

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CHAPTER 7

Multimedia Networking

People in all corners of the world are currently using the Internet to watch movies and television shows on demand. Internet movie and television distribution companies such as Netflix and Hulu in North America and Youku and Kankan in China have practically become household names. But people are not only watching Internet videos, they are using sites like YouTube to upload and distribute their own user-generated content, becoming Internet video producers as well as consumers. Moreover, network applications such as Skype, Google Talk, and QQ (enormously popular in China) allow people to not only make "telephone calls" over the Internet, but to also enhance those calls with video and multi-person conferencing. In fact, we can safely predict that by the end of the current decade almost all video distribution and voice conversations will take place end-to-end over the Internet, often to wireless devices connected to the Internet via 4G and WiFi access networks.

We begin this chapter with a taxonomy of multimedia applications in Section 7.1. We'll see that a multimedia application can be classified as either *streaming stored audio/video*, *conversational voice/video-over-IP*, or *streaming live audio/video*. We'll see that each of these classes of applications has its own unique service requirements that differ significantly from those of traditional elastic applications such as e-mail, Web browsing, and remote login. In Section 7.2, we'll examine video streaming in some detail. We'll explore many of the underlying principles behind video streaming, including client buffering, prefetching, and adapting video