AN INTERVIEW WITH...

Simon S. Lam

Simon S. Lam is Professor and Regents Chair in Computer Sciences at the University of Texas at Austin. From 1971 to 1974, he was with the ARPA Network Measurement Center at UCLA, where he worked on satellite and radio packet switching. He led a research group that invented secure sockets and prototyped, in 1993, the first secure sockets layer named Secure Network Programming, which won the 2004 ACM Software System Award. His research interests are in design and analysis of network protocols and security services. He received his BSEE from Washington State University and his MS and PhD from UCLA. He was elected to the National Academy of Engineering in 2007.

Why did you decide to specialize in networking?

When I arrived at UCLA as a new graduate student in Fall 1969, my intention was to study control theory. Then I took the queuing theory classes of Leonard Kleinrock and was very impressed by him. For a while, I was working on adaptive control of queuing systems as a possible thesis topic. In early 1972, Larry Roberts initiated the ARPAnet Satellite System project (later called Packet Satellite). Professor Kleinrock asked me to join the project. The first thing we did was to introduce a simple, yet realistic, backoff algorithm to the slotted ALOHA protocol. Shortly thereafter, I found many interesting research problems, such as ALOHA's instability problem and need for adaptive backoff, which would form the core of my thesis.

You were active in the early days of the Internet in the 1970s, beginning with your student days at UCLA. What was it like then? Did people have any inkling of what the Internet would become?

The atmosphere was really no different from other system-building projects I have seen in industry and academia. The initially stated goal of the ARPAnet was fairly modest, that is, to provide access to expensive computers from remote locations so that many more scientists could use them. However, with the startup of the Packet Satellite project in 1972 and the Packet Radio project in 1973, ARPA's goal had expanded substantially. By 1973, ARPA was building three different packet networks at the same time, and it became necessary for Vint Cerf and Bob Kahn to develop an interconnection strategy.

Back then, all of these progressive developments in networking were viewed (I believe) as logical rather than magical. No one could have envisioned the scale of the Internet and power of personal computers today. It was a decade before appearance of the first PCs. To put things in perspective, most students submitted their computer programs as decks of punched cards for batch processing. Only some students had direct access to computers, which were typically housed in a restricted area. Modems were slow and still a rarity. As a graduate student, I had only a phone on my desk, and I used pencil and paper to do most of my work.

Where do you see the field of networking and the Internet heading in the future?

In the past, the simplicity of the Internet's IP protocol was its greatest strength in vanquishing competition and becoming the *de facto* standard for internetworking. Unlike competitors, such as X.25 in the 1980s and ATM in the 1990s, IP can run on top of any link-layer networking technology, because it offers only a best-effort datagram service. Thus, any packet network can connect to the Internet.

Today, IP's greatest strength is actually a shortcoming. IP is like a straitjacket that confines the Internet's development to specific directions. In recent years, many researchers have redirected their efforts to the application layer only. There is also a great deal of research on wireless ad hoc networks, sensor networks, and satellite networks. These networks can be viewed either as stand-alone systems or link-layer systems, which can flourish because they are outside of the IP straitjacket.

Many people are excited about the possibility of P2P systems as a platform for novel Internet applications. However, P2P systems are highly inefficient in their use of Internet resources. A concern of mine is whether the transmission and switching capacity of the Internet core will continue to increase faster than the traffic demand on the Internet as it grows to interconnect all kinds of devices and support future P2P-enabled applications. Without substantial overprovisioning of capacity, ensuring network stability in the presence of malicious attacks and congestion will continue to be a significant challenge.

The Internet's phenomenal growth also requires the allocation of new IP addresses at a rapid rate to network operators and enterprises worldwide. At the current rate, the pool of unallocated IPv4 addresses would be depleted in a few years. When that happens, large contiguous blocks of address space can only be allocated from the IPv6 address space. Since adoption of IPv6 is off to a slow start, due to lack of incentives for early adopters, IPv4 and IPv6 will most likely co-exist on the Internet for many years to come. Successful migration from an IPv4-dominant Internet to an IPv6-dominant Internet will require a substantial global effort.

What is the most challenging part of your job?

The most challenging part of my job as a professor is teaching and motivating *every* student in my class, and *every* doctoral student under my supervision, rather than just the high achievers. The very bright and motivated may require a little guidance but not much else. I often learn more from these students than they learn from me. Educating and motivating the underachievers present a major challenge.

What impacts do you foresee technology having on learning in the future?

Eventually, almost all human knowledge will be accessible through the Internet, which will be the most powerful tool for learning. This vast knowledge base will have the potential of leveling the playing field for students all over the world. For example, motivated students in any country will be able to access the best-class Web sites, multimedia lectures, and teaching materials. Already, it was said that the IEEE and ACM digital libraries have accelerated the development of computer science researchers in China. In time, the Internet will transcend all geographic barriers to learning.

CHAPTER 6

Wireless and Mobile Networks

In the telephony world, the past 15 years have arguably been the golden years of cellular telephony. The number of worldwide mobile cellular subscribers increased from 34 million in 1993 to nearly 5.5 billion subscribers by 2011, with the number of cellular subscribers now surpassing the number of wired telephone lines. The many advantages of cell phones are evident to all—anywhere, anytime, untethered access to the global telephone network via a highly portable lightweight device. With the advent of laptops, palmtops, smartphones, and their promise of anywhere, anytime, untethered access to the global Internet, is a similar explosion in the use of wireless Internet devices just around the corner?

Regardless of the future growth of wireless Internet devices, it's already clear that wireless networks and the mobility-related services they enable are here to stay. From a networking standpoint, the challenges posed by these networks, particularly at the link layer and the network layer, are so different from traditional wired computer networks that an individual chapter devoted to the study of wireless and mobile networks (i.e., *this* chapter) is appropriate.

We'll begin this chapter with a discussion of mobile users, wireless links, and networks, and their relationship to the larger (typically wired) networks to which they connect. We'll draw a distinction between the challenges posed by the *wireless* nature of the communication links in such networks, and by the *mobility* that these wireless links enable. Making this important distinction—between wireless and