Computer Networks

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Architecture, Protocols, and Software

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Preface

Writing a high-tech book is an obligation; it is also a privilege.

Motive for Writing This Book

In 1962, while I was working in Taiwan, most of my classmates from the Electrical Engineering Department of National Taiwan University were in the United States attending graduate schools. One of them, Albert Hung, wrote me, "I came, I saw, and I conquered." He had just received an offer from Ford and was promised a new Fairlane at a huge discount. Several friends of mine sent me money so I, too, could come to America. I paid $350 for a propeller airplane ticket, and it took me two full days to get to this promised land. The plane stopped at Okinawa, Guam, Wake Island, and Hawaii before landing in Oakland, California. My total flying time was 39 hours. Today, not only has the flying time been reduced to one-third of that time, so has the price. And technology has made the difference.

After waiting at the airport for more than five hours, I was quite anxious. Bob Chen finally sent a friend of his to pick me up after midnight. When our car passed by the Bay Bridge, the taillights of other cars twinkled like multiple red streams. I was astonished and impressed. The next day, Bob drove me to town and showed me around the restaurants in San Francisco where, he said, I could get a job. He also said that we should study computers and told me to read the book, *Switching Circuits And Logical Design* by S. H. Caldwell. Bob's vision was right. We have all studied and loved computers ever since. Both Albert and Bob were project managers when they passed away in their early fifties. Their dedication and passion set a standard that I strive to emulate in my work.

By the end of 1990, Bob suggested that I write a book on computer networks so people could understand what networks are about. I didn't start until the summer of 1993. It turned out to be an extraordinary experience for me. As a consultant, other people listen to you. As an author, it is the other way around.

Who Should Read This Book

This book explores fundamental design concepts of computer networking and explains why such designs are important. As a prerequisite, readers should understand the basic concept of programming languages and the internal workings of a modern computer. The intended audience is composed of:

- *The upper division undergraduate and graduate students of computer science or engineering*: The materials in the book can be lectured in 30 to 60 hours.
- *Practitioners*: The book also contains very valuable technical information, so anyone can read this book to gain a better understanding of computer networks.

Although there are many approaches to designing computer networks, the basic system concept remains the same. Adding network access methods to a conventional operating system, we obtain a network operating system. The network access methods are complicated, but over the years we have made progress in designing such software.

Organization of This Book

Technologies come and go, but the basic theories remain. It is vital for us to have the ability to absorb new knowledge. Hence, both fundamental and cutting edge information are included in this book, which is divided into ten chapters. Chapters 1, 2, 3, 5, 7, and 8 cover the fundamentals of computer networking, and Appendix A contains operating system essentials. Chapters 4 and 6 cover the special design features of both local area and wide area networks currently under development. Chapters 9 and 10 provide network information of general interest. A brief description of each chapter is given below.

Chapter 1: The first chapter provides an introduction to interprocessor communications, network architecture, network topologies, applications, network operating systems, network access methods, the OSI model, layer primitives, protocol data units, the communication processor, the host processor, performance issues, and program design language.

Chapter 2: The physical layer chapter discusses topics such as transmission media, transmission modes, waveforms, Fourier analysis, signal attenuation/distortion, modulation, multiplexing, Nyquist theorem, Shannon theorem, switching methods, and the physical layer software.

Chapter 3: The data link layer chapter covers design issues, such as error detecting codes, CRC, FCS, sliding window protocols, error control, character

stuffing, bit stuffing, piggybacking, and software simulations. An attempt was made to design a data link operating in full-duplex mode. Protocols, such as XMODEM, BSC, SDLC, and HDLC are also examined.

Chapter 4: Chapter 4 is on local area networks. Because various clever technologies are employed, a medium access control sublayer must be in place to solve the contention problem. Case studies, such as Ethernet, Fast Ethernet, token ring, token bus, fiber distributed data interface, and distributed queue dual bus, are all treated with thoroughness.

Chapter 5: The network layer chapter discusses routing issues. Topics include virtual circuit model, datagram model, routing table design, and road signs. Routing philosophies, buffering techniques, and congestion control are also discussed. An attempt was made to design a packet-based *N* layer. Case studies include the X.25 packet layer protocol, Internet protocol, and Internet control message protocol. Network or switching devices, such as packet assemblers/disassemblers, bridges, routers, and gateways are also discussed.

Chapter 6: The high-speed wide area networks have growing importance. Fast network services, such as frame relay, asynchronous transfer mode, and switched multimegabit data services, are described. Both narrowband and broadband ISDNs are addressed because of their impact on the future.

Chapter 7: The transport layer includes design issues, such as segmentation/reassembly, multiplexing, connection management, error control, congestion control, finite state machine models, and permanent ports. Case studies include the OSI transport protocols (Classes 0–4), the transmission control protocol, and the user datagram protocol.

Chapter 8: The session layer should be designed as a system interface between the user program and the NOS. Basic issues include session connection/disconnection, security checks, data transfers, and synchronization. Advanced program-to-program communications and socket programming are introduced. File transfer server to support multiclients, the group talk program, and the OSI session layer are also discussed.

Chapter 9: This chapter covers upper layer service routines. Presentation services include data compression/decompression, conversion, encryption/decryption, abstract syntax notation, and so forth. Application services include message handling systems, directory services, file transfer, access, and management.

Chapter 10: The last chapter addresses network management issues such as throughput, transmission speed, response time, queuing delays, error rate, and reliability. Monitoring devices, the simple network management protocol, and the management information base are also discussed.

In addition to reference lists at the end of each chapter and a selected bibliography, products and standards that appear in brackets throughout the book are listed in Appendix C.

Acknowledgments

This book was reviewed by many individuals who have provided criticisms and valuable suggestions. In particular, I wish to thank Jim Gray, who has been a friend since graduate school. Wesley Chu has provided both encouragement and support. My students, including Diller Ryan, Greg Bostrom, Don Erickson, Matt Dukleth, Johnanna Madjedi, Steve Lau, and Zac Kaufman were all helpful. I salute all the reviewers who have made a great contribution in shaping the manuscript to its final form. Some of their names and affiliations are listed below.

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John Y. Hsu
San Luis Obispo, CA

Contents

Introduction to Computer Networks

1

Day, night after flight.
the flock is nowhere in sight. Keep going.

Physically, a computer network is merely a collection of interconnected computers. Each computer is an autonomous node running its own operating system (OS) (i.e., a set of control programs). The terms OS, control programs, system software, or just system all have the same semantic meaning. The term *system* means system software, system hardware, or system software and hardware combined. Computer network architecture refers to the general design of a computer network, which involves both hardware and software. Needless to say, the system hardware is developed to support system software, and the reverse is also true.

The access methods (AMs) in an OS are the input/output (I/O) system routines grouped together to access data on an external device, such as disk, tape, display, or printer. Simply put, the I/O system or subsystem is part of an operating system. The network access methods (NAMs) are the network I/O system routines designed to transmit and receive data between two computers. In other words, the NAMs are developed so that a program running on one processor can communicate with another program running on a different processor. The entire set of control programs running on the node in a computer network constitutes the network operating system (NOS). Hence, the NOS is comprised of all the control programs in an OS plus the system software for network I/O and management. In other words, the NOS is a superset of OSs in that it supports network communications between two user application programs running on two different computers. The two computers may be situated in one room, or they may be 3,000 miles apart. This chapter will introduce the physical layout, applications, protocols, and software design of computer networks.