

Preface

Since the early 1990s coupled with the widespread deployment of broadband to the home, we have seen remarkable progress in the ease of Internet accessibility to end users. Both commercial and private sectors rely heavily on the availability of the Internet to conduct normal day-to-day functions. Underpinning this exponential growth in popularity of the Internet are the advances made in the applications of basic algorithms to design and architect the Internet. The most obvious example of these algorithms is the use of search engines to collect and correlate vast amounts of information that is spread throughout the Internet.

With the dawn of this new century, we are now on the verge of expanding the notion of what we mean to communicate. A new generation of netizens are poised to leverage the Internet for a myriad different applications that we have not envisioned thus far. This will require that the Internet be flexible and adapt to accommodate the requirements of next-generation applications. To address this challenge, in the United States, the National Science Foundation has initiated a large research project GENI. The goal of GENI is to perform a clean-slate design for a new Internet. In particular, the aim of this project is to rethink the basic design assumptions on which the current Internet is built, with the possibility that to improve flexibility for new services we may arrive at a radically different Internet, beyond what one might imagine from evolving the current network. Given this context of Internet research, the purpose of this book is to provide a comprehensive survey of present algorithms and methodologies used in the design and deployment of the Internet. We believe that a thorough understanding of algorithms used by the Internet today is critical to develop new algorithms that will form the basis of the future Internet.

The book is divided into three parts dealing with the application of algorithms to different aspects of network design, operations, and next-generation applications. Part I provides an algorithmic basis for the design of networks both at the physical and the service layer. This part is extensive since it considers different physical layer network technologies. The first chapter in this part outlines the goals for optimization in network design by considering both the optimizability of protocols and the optimum placement of network functionality. The general idea of Valiant load balancing, and its application in the context of efficient network design, is presented in Chapter 2.

Understanding the influence of physical network characteristics in the design of network services is critical to develop robust network services. The algorithms described in this part explicitly model physical and network level constraints while also discussing design tradeoffs made for practical implementation. Algorithms used for optimal capacity provisioning in optical networks and spectrum management in wireless networks are covered in Chapters 3 and 4. In order to maximize network throughput, it is necessary that design algorithms take into account the impact of physical network constraints such as interference on network performance. This awareness of the physical layer in the design of network level optimizations, also called cross-layer algorithms, is presented in Chapter 5. In Chapter 6 the constraint of radio interference is extended to the resource allocation problems of cellular networks. Chapter 7 considers several aspects that are involved in the definition of new network services such as addressing and traffic class definitions with a special emphasis on Ethernet-based services.

Several popular applications such as P2P file sharing applications employ overlay networks. Overlay networks are defined by the end user and constructed over the current Internet. As overlay network services become popular and make increasing demands on the network infrastructure it is becoming necessary to optimize network performance by considering the interactions of the different overlay networks. Overlay networks must also account for the coexistence of underlay services in the basic network infrastructure. Algorithms that are aimed at addressing these challenging issues are discussed in Chapter 8.

The second part of this book covers two important topics of network operations and management. As we know today, network providers have already completed field trials for the 100 Gbps network. It should not be long before these capacities become commonplace on the Internet. The challenge of processing packets at such high speeds imposes a tremendous significance on efficient and fast packet-processing algorithms. Chapter 9 surveys the area of Hash-based techniques for high-speed packet processing, and Chapter 10 goes into the next level of detail by surveying fast packet pattern matching algorithms. These techniques can be naturally extended to other network applications such as security and high-speed network monitoring.

In the face of ever-increasing heterogeneity in applications, services, and technologies, network management has been a difficult challenge for the Internet today. Quite often there is no clear picture of what the normal behavior of networks should be. In this book, we begin the discussion on network management in Chapter 11 with a survey of anomaly detection approaches with a special focus on unsupervised learning algorithms. There are a few instances when the model of the anomalous behavior is available and this is especially true in the case of physical networks. Chapter 12 discusses a model-based anomaly detection approach for the optical transmission system. We also present two different philosophies for network monitoring, the in-network monitoring in Chapter 13, and the end-to-end monitoring in Chapter 14.

Part III of this book discusses algorithmic techniques that form the basis of emerging applications. The part starts with the discussion in Chapter 15 on Network

coding and its applications to communication networks. The algorithms that underlie the ubiquitous Internet search applications such as Yahoo and Google are surveyed in Chapter 16. However, as the nature and the modes of usage of this content on the Internet evolves the requirements of these search engine algorithms must also evolve. This chapter provides perspectives on how this evolution is taking place.

Until today the Internet has been used primarily for point-to-point and mostly for non-interactive communications. However, this is quickly changing as evidenced by the growing online gaming industry. Online gaming and the algorithms that implement these games at the client, server, and network are discussed in Chapter 17. Online gaming has opened up the possibility of exploring more real-time communications such as Telepresence on the Internet. It is expected that the next generation of communication services will leverage this interactively to make communications more content-rich. Social networking is one example of next-generation communications. Using online social networks, communities are being built across the world based on user group interests. Algorithms that attempt to describe the building and evolution of these online social networks are discussed in Chapter 18. These social networks also have the potential to evolve into interactive communication groups, therefore understanding their evolution patterns is critical from a network operations and management perspective.

In this book we have attempted to provide a flavor of how algorithms have formed the basis of the Internet as we know it today. It is our hope that this book will provide a useful overview of algorithms applied to communication networks, for any student who aspires to do research in network architecture as well as the application of algorithms to communication networks. We believe that for a robust design of the future Internet, it is essential that the architecture be founded on the basis of sound algorithmic principles.

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