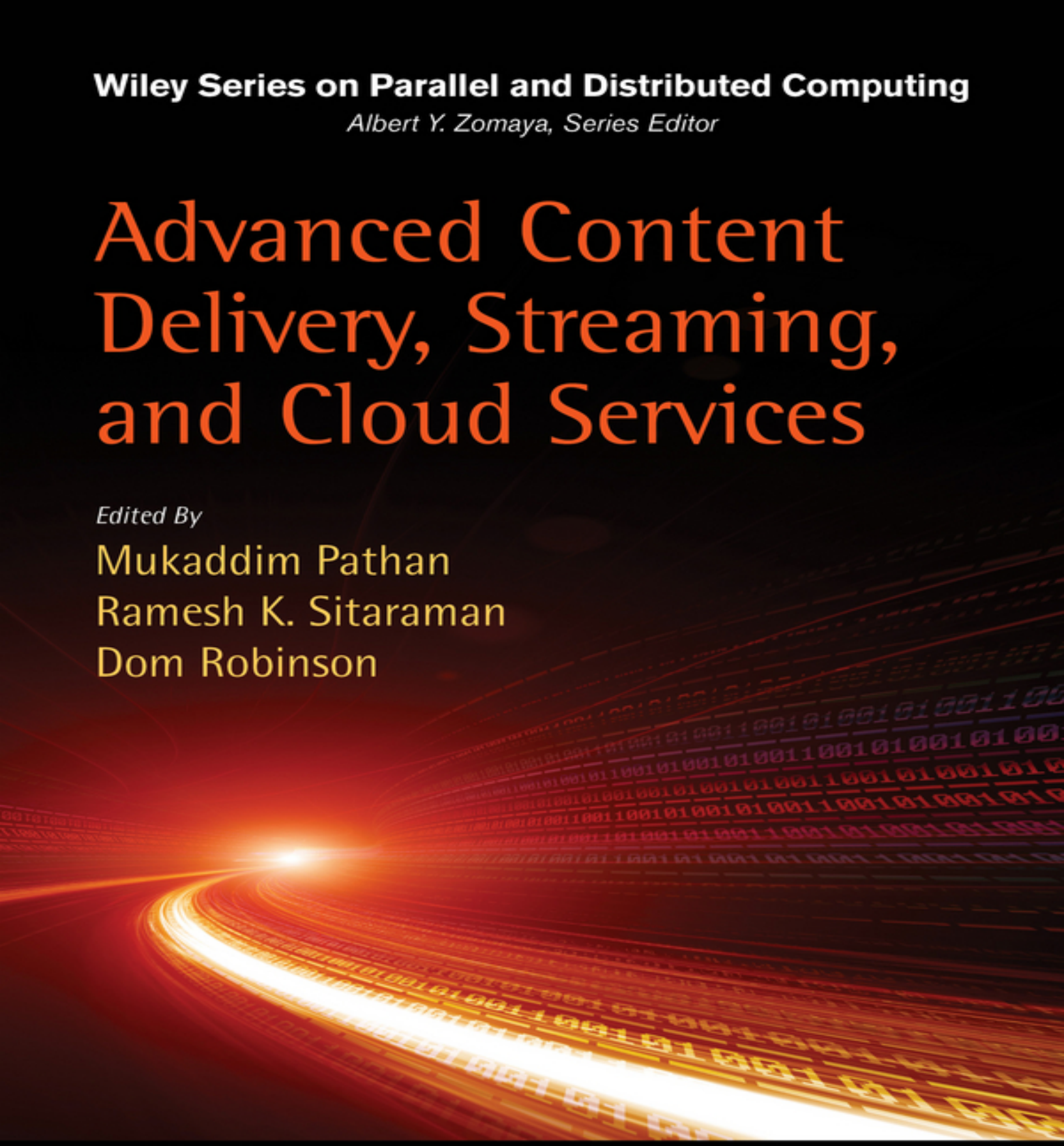
Wiley Series on Parallel and Distributed Computing

Albert Y. Zomaya, Series Editor

Advanced Content Delivery, Streaming, and Cloud Services

Edited By

Mukaddim Pathan
Ramesh K. Sitaraman
Dom Robinson



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To my wife Ziyuan for her inspiration, love, and support. This book would not have been completed, if she did not single-handedly take care of everything, while I was too busy in writing and compilation!—Mukaddim

To my wife Vidya and our active children Anu and Siddu for whom the Internet can never be fast enough!—Ramesh

To my wife Mariana and our wonderful kids Sofia and Zac—I am sure you will enjoy this book as a bedtime reading. And to my parents (that funny "computer thing" you bought me as a kid came in handy!)—Dom

Preface

The ever-evolving nature of the Internet brings new challenges in managing and delivering content to end-users. Content Delivery Networks (CDNs) improve Web access and streaming performance, in terms of response time and system throughput, while delivering content to Internet end-users through multiple, geographically distributed edge servers. The CDN industry, that is, content delivery, consumption, and monetization, has been undergoing rapid changes. The multidimensional surge in content delivery from end-users has led to an explosion of new content, formats, and an exponential increase in the size and complexity of the digital content supply chain. These changes have been accelerated by economic downturn in that the content providers are under increasing pressure to reduce costs while increasing revenue.

The main value proposition for CDN services has shifted over time. Initially, the focus was on improving end-user-perceived experience by decreasing response time, especially when the customer website experiences unexpected traffic surges. Nowadays, CDN services are treated by content providers as a way to use a shared infrastructure to handle their peak capacity requirements, thus allowing reduced investment cost in their own hosting infrastructure. Moreover, recent trends in CDNs indicate a large paradigm shift toward a utility computing model, which allows customers to exploit advanced content delivery services, hosted on commodity hardware, without having to build a dedicated infrastructure.

From a market perspective, historically buyers based the bulk of demand and spending on “core” CDN products that

facilitate the delivery of Web-based content services. Over the last few years, offering from video streaming and value-added services (VASs) peaked as the most demandable CDN products. They formed the basis of most of the present-day CDNs' offering, while strong demand for the basic CDN services still continues. Market research shows that on average, buyers reported 43% of total CDN spending on core products, such as caching and content delivery, while 57% spending on VAS-based products.

While satisfying the market demands, CDN providers are more and more focusing on higher margin, VAS offering in order to gain (or stabilize) overall profit margins. These VASs include mobile data acceleration, content protection, content management, application acceleration, mobile data delivery, and cloud-based storage. While these products currently have a reasonable market penetration, they represent even more substantial near-term growth opportunities.

In addition to the emergence of innovative CDN models, such as managed CDNs, licensed CDNs, and federated CDNs, Telco/operator CDNs are evolving into major market share holders. Telcos/operators around the world have started building CDN platform, technology, and support to aid content consumption, delivery, and rich media experience by end-users. The geographic expansion of Web-based content continues to grow and drive global CDN business requirements. Many CDN players have started with a regional focus and then expanded to offer services in new regions. It is expected that these trends in the CDN industry will continue, as the definition and scope of a CDN gets broader.

1.1 Overview and Scope of the Book

The book entitled *Advanced Content Delivery, Streaming, and Cloud Services* presents fundamental and trendy CDN technologies, with a comprehensive coverage of evolution, current landscape, and future roadmap. The book builds on academic and industrial research and developments, and case studies that are being carried out at different organizations around the world. In addition, the book identifies potential research directions and technologies that will drive future innovations. This book is aimed at a large audience including systems architects, practitioners, product developers, and researchers. It can be used as a reference/textbook for graduate students and a roadmap for academicians, who are starting to research in the field of content delivery. We expect the readers to have at least the basic knowledge about Web technologies and the Internet. In particular, readers should be knowledgeable about Web caching, replication, Internet-based services and applications, and basic networking.

Upon reading this, book readers will perceive the following benefits:

1. Learn the state of the art in research and development on content management, delivery, and streaming technologies.
2. Obtain a future roadmap by learning open research issues.
3. Gather the background knowledge to tackle key problems, whose solutions will enhance the evolution of next-generation content networks.
4. Use the book as a valuable reference and/or textbook.

1.2 Organization of the Book

This book is organized into three parts, namely, Part I: CDN and Media Streaming Basics; Part II: CDN Performance Management and Optimization; and Part III: Case Studies and Next-Generation CDNs. Specifically, the topics of the book are the following:

- *CDN*—Infrastructure, architecture, and technology for web content delivery, content management services, and media streaming.
- *Adaptive Bitrate Streaming (ABR).* Techniques for multimedia streaming over computer networks using the HTTP protocol.
- *Cloud-Based Content Delivery.* Integration of cloud computing with traditional CDN model for content and Web application delivery.
- *Wide Area Network (WAN) Optimization.* Optimization algorithms to increase data transfer efficiency in an end-to-end delivery path across WANs.
- *Mobile Acceleration Service.* Optimizing content and video streams to mobile devices to meet dynamic and personalized content needs of mobile users.
- *Transparent Caching.* Carriers network caching technology to control over what content to cache, when to cache, and how fast to accelerate the content delivery.
- *Request-Routing Techniques.* Known and advanced algorithms for redirecting end-user requests, such as DNS-based routing, anycasting, and content-based routing.
- *CDN Performance, Availability, and Reliability.* SSL processing, network-based personal video recorder (PVR), and measurement techniques.

- *Next-Generation CDNs*. Overview of managed/licensed CDN, Telco/carrier CDNs, P2P CDN, and federated CDNs.
- *CDN Case Studies*. Overview of operational infrastructure and services from the major CDNs.
- *CDN Business Intelligence*. Coverage of the CDN market trends, ongoing planning, and management.

Part I of the book focuses on the basic ideas, techniques, and current practices related to content delivery and media streaming. Chapter 1 by Pathan presents an overview of CDNs, operational models, and use cases. It covers recent market and technology trends, as well as identifies a few research issues in the CDN domain. Robinson, in Chapters 2 and 3, provides a comprehensive description of the live media streaming ecosystem and demonstrates the practical configuration of live streaming using a few tools. In Chapter 4, Haßlinger identifies key properties of caching and content delivery in broadband access network, and describes how efficiency can be achieved by configuration and performance tuning. Alzoubi et al. in Chapter 5 present mechanisms and algorithms to effectively redirect end-user requests in a CDN platform. This chapter demonstrates the applicability of IP anycasting for request redirection. Basics of content delivery to cloud-based home ecosystem is covered in Chapter 6 by Cruz et al., highlighting key challenges, industry practices, and recent trends. In Chapter 7, Narayanan et al. describe the challenges in delivering video in mobile networks and present various adaptation techniques for mobile video streaming.

Part II of the book provides a coverage of CDN performance measurement techniques, tools, reporting, and analytics. In Chapter 8, Siglin covers CDN analytics tools and explores a variety of analytic practices and their

implications in practical context, including new methods for analyzing adaptive bitrate (ABR) streaming technology. Mathematical modeling to optimize CDN services, such as video on demand (VoD) content delivery, is covered in Chapter 9 by Bekta$ and Ercetin. It makes the reader aware of fundamental optimization problems arising in content delivery and the ways of effectively solving these problems. Molina et al. in Chapter 10 present a basic analytical model to analyze the basic and advanced properties of a CDN. Zhanikeev in Chapter 11 describes a method for cloud-based multisource streaming and compares its performance over traditional methods. In Chapter 12, Islam and Grégoire discuss on the intersection of CDN and cloud computing by exposing a number of trade-offs on the deployment of multimedia processing functions inside the cloud and identify relevant performance factors. In Chapter 13, Yoshida describes the performance of a dynamic streaming CDN, comprising techniques for dynamic network reorganization, and load distribution and balancing to realize dynamicity, as well as techniques for stream segmentation and reconstruction, and QoS assurance. Cesario et al. in Chapter 14 present the analysis of mining streaming data in a CDN, improving efficiency and effectiveness of a CDN architecture. A hybrid multidomain architecture is described that solves the problem of computing frequent items and frequent itemsets from distributed data streams. In Chapter 15, Davies and Pathan cover the capacity planning process that is instrumental for the ongoing operation of a deployed CDN infrastructure. It includes a practical application and workflow of the CDN capacity planning process.

Part III, the final part of the book, consists of a handful of representative case studies on present- and next-generation CDNs. In Chapter 16, Sitaraman et al. discuss different network overlays that are crucial for meeting the