



MASTERING CLOUD COMPUTING

FOUNDATIONS AND APPLICATIONS PROGRAMMING

MK
MORGAN KAUFMANN

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Mastering Cloud Computing

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Foundations and Applications Programming

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Preface

The growing popularity of the Internet and the Web, along with the availability of powerful handheld computing, mobile, and sensing devices, are changing the way we interact, manage our lives, conduct business, and access or deliver services. The lowering costs of computation and communication are driving the focus from personal to datacenter-centric computing. Although parallel and distributed computing has been around for several years, its new forms, multicore and cloud computing, have brought about a sweeping change in the industry. These trends are pushing the industry focus from developing applications for PCs to cloud datacenters that enable millions of users to use software simultaneously.

Computing is being transformed to a model consisting of commoditized services delivered in a manner similar to utilities such as water, electricity, gas, and telephony. As a result, information technology (IT) services are billed and delivered as “computing utilities” over shared delivery networks, akin to water, electricity, gas, and telephony services delivery. In such a model, users access services based on their requirements, regardless of where those services are hosted. Several computing paradigms have promised to deliver this utility computing vision. Cloud computing is the most recent emerging paradigm promising to turn the vision of “computing utilities” into a reality.

Cloud computing has become one of the buzzwords in the IT industry. Several IT vendors are promising to offer storage, computation, and application hosting services and to provide coverage on several continents, offering service-level agreements-backed performance and uptime promises for their services. They offer subscription-based access to infrastructure, platforms, and applications that are popularly termed Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS). These emerging services have reduced the cost of computation and application hosting by several orders of magnitude, but there is significant complexity involved in the development and delivery of applications and their services in a seamless, scalable, and reliable manner.

There are several cloud technologies and platforms on the market—to mention a few: Google AppEngine, Microsoft Azure, and Manjrasoft Aneka. Google AppEngine provides an extensible runtime environment for Web-based applications that leverage the huge Google IT infrastructure. Microsoft Azure provides a wide array of Windows-based services for developing and deploying Windows applications on the cloud. Manjrasoft Aneka provides a flexible model for creating cloud applications and deploying them on a wide variety of infrastructures, including public clouds such as Amazon EC2.

With this sweeping shift from developing applications on PCs to datacenters, there is a huge demand for manpower with new skill sets in cloud computing. Universities play an important role in this regard by training the next generation of IT professionals and equipping them with the necessary tools and knowledge to tackle these challenges. These institutions need to be able to set up a cloud computing environment for teaching and learning with minimal investment. One of the attractive cloud application platforms that meet this need is Manjrasoft’s Aneka, which (1) enables the construction of a private/enterprise cloud by harnessing the existing network of computers

(LAN-connected PCs), (2) provides a software development kit (SDK) that supports application programming interfaces (APIs) for multiple programming models such as Thread, Task, and MapReduce, and (3) supports, in a seamless manner, the deployment and execution of applications on diverse infrastructures such as multicore servers, private clouds, and public clouds.

Currently, expert developers are required to create cloud applications and services. Cloud researchers, practitioners, and vendors alike are working to ensure that potential users are educated about the benefits of cloud computing and the best way to harness its full potential. However, because it's a new and popular paradigm, the very definition of cloud computing depends on which computing expert is asked. So, although the realization of true utility computing appears closer than ever, its acceptance is currently restricted to cloud experts due to the perceived complexities of interacting with cloud computing providers. This book aims to change the game by simplifying and imparting cloud computing foundations, technologies, and programming skills to readers so that even average programmers and software engineers are able to develop cloud applications easily.

The book at a glance

This book introduces the fundamental principles of cloud computing and its related paradigms. It discusses the concepts of virtualization technologies along with the architectural models of cloud computing. It presents prominent cloud computing technologies that are available in the marketplace, including the Aneka Cloud Application Platform. The book contains chapters dedicated to discussion of concurrent, high-throughput, and data-intensive computing paradigms and their use in programming cloud applications. Various application case studies from domains such as science, engineering, gaming, and social networking are introduced, along with their architecture and how they leverage various cloud technologies. These case studies allow the reader to understand the mechanisms needed to harness cloud computing in their own respective endeavors. Finally, the book details many open research problems and opportunities that have arisen from the rapid uptake of cloud computing. We hope that this motivates the reader to address these in their own future research and development. The book also comes with an associated Website (hosted at www.buyya.com/MasteringClouds) that contains pointers to advanced online resources.

The book contains 11 chapters, which are organized into three major parts:

Part 1: Foundations

Chapter 1—Introduction

Chapter 2—Principles of Parallel and Distributed Computing

Chapter 3—Virtualization

Chapter 4—Cloud Computing Architecture

Part 2: Cloud Application Programming and the Aneka Platform

Chapter 5—Aneka: Cloud Application Platform

Chapter 6—Concurrent Computing: Thread Programming

Chapter 7—High-Throughput Computing: Task Programming

Chapter 8—Data-Intensive Computing: MapReduce Programming

- Part 3: Industrial Platforms and New Developments
 - Chapter 9—Cloud Platforms in Industry
 - Chapter 10—Cloud Applications
 - Chapter 11—Advanced Topics in Cloud Computing

The book serves as a perfect guide to the world of cloud computing. Starting with the fundamentals, the book drives students and professionals through the practical use of these concepts via hands-on sessions on how to develop cloud applications, using Aneka as a reference platform. Part 3 goes beyond the reference platform and introduces other industrial technologies and solutions (Amazon Web Services, Google AppEngine, and Microsoft Azure) and real applications, identifies emerging trends, and offers future directions for cloud computing.

Benefits and readership

Given the rapid emergence of cloud computing as a mainstream computing paradigm, it is essential to have both a solid understanding of the core concepts characterizing the phenomenon and a practical grasp of how to design and implement cloud computing applications and systems. This set of skills is already fundamental today for software architects, engineers, and developers because many applications are being moved to the cloud. It will become even more important in the future, when this technology matures further. This book provides an ideal blend of background information, theory, and practical cloud computing development techniques, expressed in a language that is accessible to a wide range of readers: from graduate-level students to practitioners, developers, and engineers who want to, or need to, design and implement cloud computing solutions. Moreover, more advanced topics presented at the end of the manuscript make the book an interesting read for researchers in the field of cloud computing who want an overview of the next challenges in cloud computing that will arise in coming years.

This book is a timely contribution to the cloud computing field, which is gaining considerable commercial interest and momentum. The book is targeted at graduate students and IT professionals such as system architects, practitioners, software engineers, and application programmers. As cloud computing is recognized as one of the top five emerging technologies that will have a major impact on the quality of science and society over the next 20 years, the knowledge conveyed through this book will help position our readers at the forefront of the field.

Directions for adoption: theory, labs, and projects

Given the importance of the cloud computing paradigm and its rapid uptake in industry, universities and educational institutions need to upgrade their curriculum by introducing one or more subjects in the area of cloud computing and related topics, such as parallel computing and distributed systems. We recommend that they offer at least one subject on cloud computing as part of their undergraduate and postgraduate degree programs, such as B.E./B.Tech./BSc in computer science and related areas and Masters, including the Master of Computer Applications (MCA). We believe that

this book will serve as an excellent textbook for such subjects. If the students have already had exposure to the concepts of parallel and distributed computing, Chapter 2 can be skipped.

For those aiming to make their curriculum rich with cloud computing, we recommend offering two courses: “Introduction to Cloud Computing” and “Advanced Cloud Computing,” in two different semesters. This book has sufficient content to cater to both of them. The first subject can be based on Chapters 1–6 and the second one based on Chapters 7–11.

In addition to theory, we strongly recommend the introduction of a laboratory subject that offers hands-on experience. The lab exercises and assignments can focus on creating high-performance cloud applications and assignments on a range of topics, including parallel execution of mathematical functions, sorting of large data in parallel, image processing, and data mining. Using cloud software systems such as Aneka, institutions can easily set up a private/enterprise cloud computing facility by utilizing existing LAN-connected PCs running Windows. Students can use this facility to learn about various cloud application programming models and interfaces discussed in Chapter 6 (Thread Programming), Chapter 7 (Task Programming), and Chapter 8 (MapReduce Programming). Students need to learn various programming examples discussed in these chapters and execute them on an Aneka-based cloud facility. We encourage students to take up some of the programming exercises noted in the “Review Questions” sections of these chapters as lab assignments and develop their own solutions.

Students can also carry out their final-year projects focused on developing cloud applications to solve real-world problems. For example, students can work with academics, researchers, and experts from other science and engineering disciplines, such as life and medical sciences or civil and mechanical engineering, and develop suitable applications that can harness the power of cloud computing. For inspiration, please read various application case studies presented in Chapter 10.

Supplemental materials

Supplemental materials for instructors or students can be downloaded from Elsevier: <http://store.elsevier.com/product.jsp?isbn=9780124114548>

PART

Foundations

1

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Introduction

1

Computing is being transformed into a model consisting of services that are commoditized and delivered in a manner similar to utilities such as water, electricity, gas, and telephony. In such a model, users access services based on their requirements, regardless of where the services are hosted. Several computing paradigms, such as grid computing, have promised to deliver this utility computing vision. *Cloud computing* is the most recent emerging paradigm promising to turn the vision of “computing utilities” into a reality.

Cloud computing is a technological advancement that focuses on the way we design computing systems, develop applications, and leverage existing services for building software. It is based on the concept of *dynamic provisioning*, which is applied not only to services but also to compute capability, storage, networking, and information technology (IT) infrastructure in general. Resources are made available through the Internet and offered on a *pay-per-use* basis from cloud computing vendors. Today, anyone with a credit card can subscribe to cloud services and deploy and configure servers for an application in hours, growing and shrinking the infrastructure serving its application according to the demand, and paying only for the time these resources have been used.

This chapter provides a brief overview of the cloud computing phenomenon by presenting its vision, discussing its core features, and tracking the technological developments that have made it possible. The chapter also introduces some key cloud computing technologies as well as some insights into development of cloud computing environments.

1.1 Cloud computing at a glance

In 1969, Leonard Kleinrock, one of the chief scientists of the original Advanced Research Projects Agency Network (ARPANET), which seeded the Internet, said:

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of ‘computer utilities’ which, like present electric and telephone utilities, will service individual homes and offices across the country.

This vision of computing utilities based on a service-provisioning model anticipated the massive transformation of the entire computing industry in the 21st century, whereby computing services will be readily available on demand, just as other utility services such as water, electricity, telephone, and gas are available in today’s society. Similarly, users (consumers) need to pay providers