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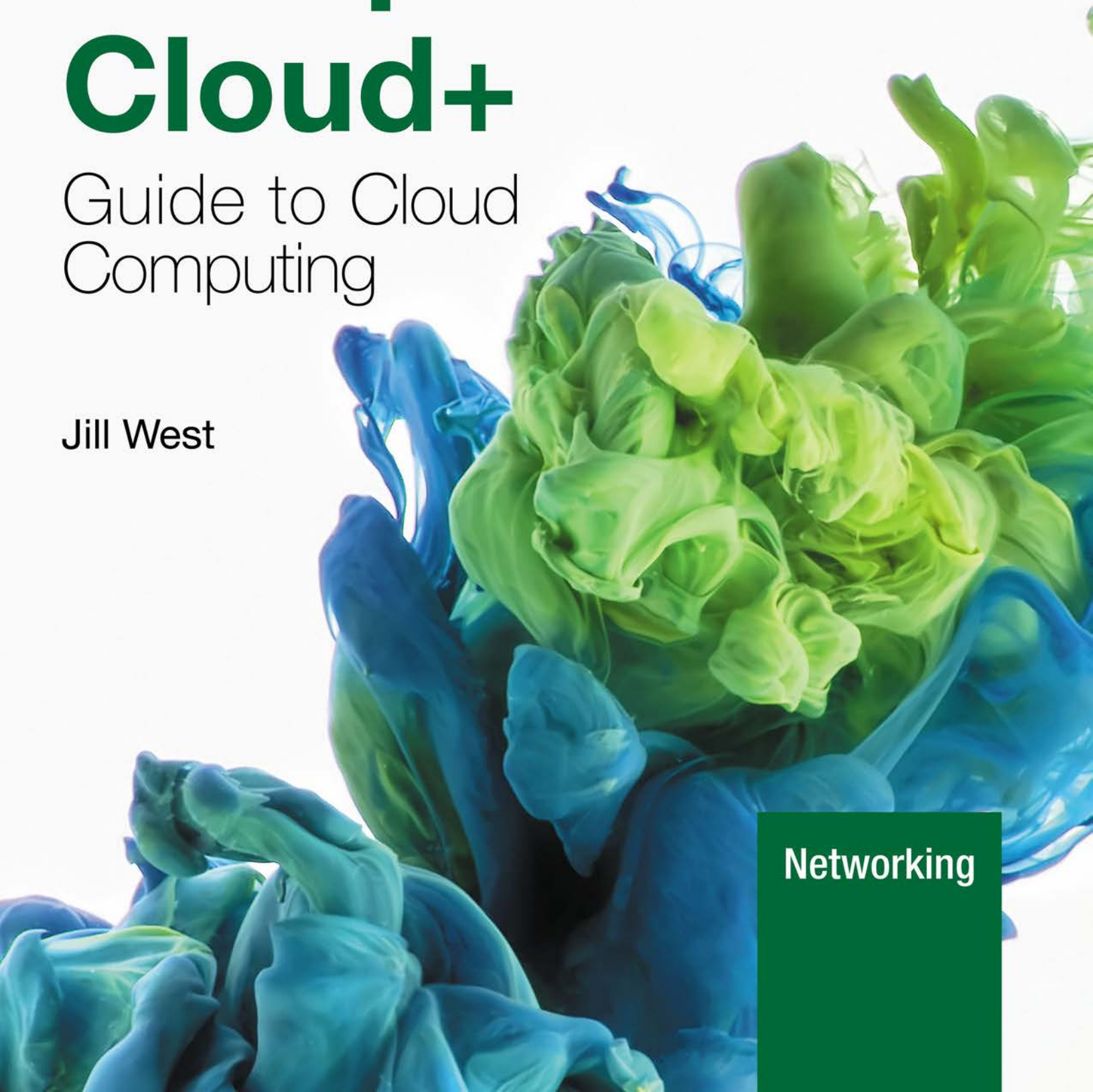
Second Edition

CompTIA Cloud+

Guide to Cloud Computing

Jill West



Networking

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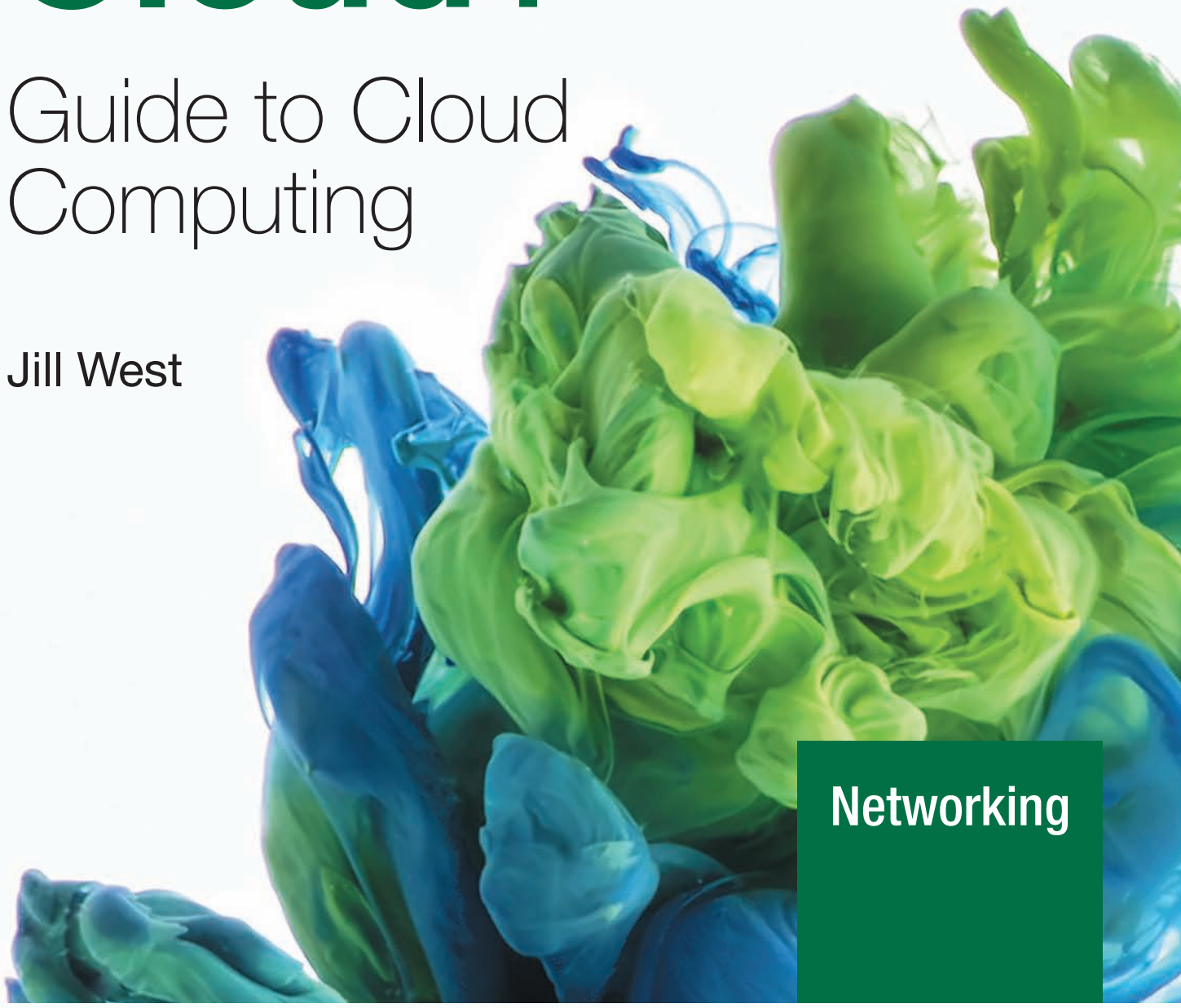

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CompTIA Cloud+Guide to Cloud Computing
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Jill West

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Cover Image Source: Sanjatosic/Shutterstock.com

Library of Congress Control Number: 2022910588

ISBN:978-0-357-88345-7

Cengage
200 Pier 4 Boulevard
Boston, MA 02210
USA

Printed in the United States of America
Print Number: 01 Print Year: 2022

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Preface

CompTIA Cloud+ Guide to Cloud Computing, 2nd edition, is intended to serve the needs of students and professionals who are interested in mastering fundamental, vendor-independent cloud computing concepts. No previous cloud computing experience is necessary to begin learning from this course, although knowledge of basic computer, networking, and security principles is helpful. Those seeking to pass CompTIA's Cloud+ certification exam will find the course's content, approach, and numerous projects and study questions especially helpful. For more information on CompTIA Cloud+ certification, visit CompTIA's website at comptia.org.

Module Descriptions

The following list summarizes the topics covered in each module of this course:

Module 1, "Introduction to Cloud Computing," gives an initial overview of foundational cloud computing concepts, beginning with a survey of cloud certifications, a review of characteristics that define cloud computing, and a description of how an IT professional must adapt existing skills to succeed in a career focused on cloud technologies. The module then compares cloud deployment models (such as public cloud and hybrid cloud), cloud service models (such as PaaS and IaaS), and security concerns specific to each of these models. Finally, the module introduces popular cloud platforms, such as AWS (Amazon Web Services), Microsoft Azure, and GCP (Google Cloud Platform), and reviews sound troubleshooting methodology.

Module 2, "Virtual Hardware," begins with a description of virtualization technologies, including a thorough comparison of type 1 and type 2 hypervisors. The module then takes a deep dive into VM (virtual machine) configuration parameters, especially virtualized processing and virtual memory. It then applies these concepts specifically to the context of cloud computing, followed by a survey of VM allocation factors. The module concludes with coverage of VM alternative technologies such as serverless computing and containers.

Module 3, "Migration to the Cloud," focuses on how to get existing resources into the cloud. The module explores factors to be considered before, during, and after migration, including a comparison of migration strategies (such as lift-and-shift and lift-tinker-and-shift), and the timing of migration tasks that might affect user experience. Related migration topics include documentation, change management processes, and data transfer technologies. The module proceeds to discuss types of testing used to help the migration go smoothly. It also covers business processes that serve application development, such as project management and the application life cycle. The module concludes with a synopsis of common problems encountered during migration as well as planning for business continuity and disaster recovery.

Module 4, "Cloud Networking," initiates the discussion of cloud-based networking concepts with a comparison of the OSI Model and the cloud stack. The module includes a review of IP addressing and subnetting concepts followed by an exploration of networking services in AWS, Azure, and GCP. These sections include a thorough discussion of concepts such as regions, availability zones, VPCs (virtual private clouds), VNets (virtual networks), subnetting in the cloud, and the use of gateways and route tables to manage cloud traffic.

Module 5, "Cloud Connectivity and Troubleshooting," continues the cloud networking discussion with an exploration of technologies that connect the on-prem network with cloud-based resources. Network segmentation on-prem is contrasted with network segmentation in the cloud. The module explores technologies available to extend networking services across a hybrid or multi-cloud, such as DHCP, DNS, routing, and load balancing. It concludes with an overview of available CLI (command-line interface) commands used to troubleshoot cloud connectivity as well as situations where these tools might be useful.

Module 6, "Securing Cloud Resources," introduces security-related threats specific to cloud computing. While security is addressed throughout most of the modules, this module brings additional focus to cloud-based security strategies. The module highlights concerns and techniques specific to virtual network security, compute security, and data security, followed by an overview of common security weak spots in the cloud.

Module 7, "Identity and Access Management," furthers the security discussion with thorough coverage of IAM (identity and access management) techniques used to control access to cloud resources. The module covers account types that offer identity services to human users and application or cloud services, followed by a thorough discussion of authentication technologies and tools used in a cloud environment. Continuing with the theme of the three-tiered AAA (authentication, authorization, and accounting) approach to network access control, the module then explores options for managing authorization and permissions in AWS, Azure, and GCP. The module concludes with a brief discussion of how to extend IAM across a hybrid cloud as well as common IAM troubleshooting issues.

Module 8, "Cloud Storage," explains common storage technologies both on-prem and in the cloud, followed by storage optimization techniques. The module then highlights popular storage services in AWS, Azure, and GCP. It continues with an exploration of common backup types and techniques, including clones, snapshots, and redundancy levels. The module concludes with an emphasis on the security of cloud-hosted data storage.

Module 9, "Managing Cloud Performance," illustrates the need for effective monitoring techniques in the cloud along with an introduction to the benefits realized when automating cloud management tasks. Following a comparison of data collection tools—such as metrics, events, and logs—the module continues with coverage of analysis and response tools available in AWS, Azure, and GCP. Finally, the module explores common performance and capacity issues.

Module 10, "Cloud Automation," rounds out the foundations of cloud computing with further exploration into the possibilities and sheer necessity of using automation techniques in the cloud. Due to the fast-paced changes constantly occurring in cloud configurations and customer demand, automation through IaC (infrastructure as code) technologies provides adaptable and efficient modifications performed by tools covered in this module. The module then explores maintenance, security, and disaster recovery techniques that can be automated, including in-depth coverage of CLI and patch management tools available in AWS, Azure, and GCP. The module finishes with coverage of common obstacles to establishing successful automation workflows.

Features

To aid you in fully understanding cloud computing concepts, this course includes many features designed to enhance your learning experience.

- ***Running scenario***—Each module begins with a running scenario giving real-world context for the technology and concepts presented. The ongoing story provides insight into a variety of cloud computing challenges from the perspective of an IT team preparing to migrate its data center to the cloud.
- ***Module objectives***—Each module lists the concepts to be mastered within that module. This list serves as a quick reference to the module's contents and as a useful study aid.
- ***Scenario-based practice questions***—Each module includes scenario-based questions similar to what you might encounter on the CompTIA Cloud+ exam. These questions put module content in real-world context and provide on-time application of covered concepts.
- ***Colorful illustrations, screenshots, tables, and bulleted lists***—Numerous full-color diagrams illustrating abstract ideas and screenshots of various cloud platform consoles help you visualize common cloud computing tools, theories, and concepts. In addition, the many tables and bulleted lists provide details and comparisons of both practical and theoretical information that can be easily reviewed and referenced in the future.
- ***Notes and CompTIA Cloud+ Exam Tips***—Each module's content is supplemented with Notes that provide additional insight and understanding, while CompTIA Cloud+ Exam Tips guide you in your preparations for taking the certification exam.
- ***Cengage Unlimited cross-references***—If you have a Cengage Unlimited subscription, convenient cross-references to other publications with additional information on relevant concepts invite further study and exploration.
- ***You're Ready prompts***—As you read through each module, you'll encounter prompts that indicate when you're ready for a specific project, inviting you to customize your learning path with what works best for your learning style.

- ***Key Terms and Glossary***—Key terms emphasize the core concepts of cloud computing and are defined in the convenient Glossary.
- ***Module summaries***—Each module concludes with a summary of the concepts introduced in that module. These summaries help you revisit the ideas covered in the module.
- ***Acronyms table***—As in all things IT, cloud computing relies on extensive use of acronyms. The CompTIA Cloud+ objectives include a list of acronyms pertinent to the exam content, and a table at the end of each module indicates which of these acronyms are covered in that module.
- ***Hands-On Projects***—Although it is important to understand the theory behind cloud computing technology, nothing beats real-world experience. To this end, each module provides several Hands-On Projects aimed at providing you with practical implementation experience as well as practice in applying critical thinking skills to the concepts learned in the module. Hands-On Projects use free trial or free student accounts in the three major cloud platforms: Amazon Web Services, Microsoft Azure, and Google Cloud Platform.
- ***User-friendly organization***—Logical arrangement of content consolidates similar concepts for efficient coverage. This organization gives you the opportunity for deeper investigation of particularly rich concepts and skills that are emphasized in the latest CompTIA Cloud+ CVO-003 exam. Topics include a strong emphasis on security, troubleshooting, and business requirements, with expanded coverage of IoT (Internet of Things), containers, and cloud within a cloud concepts.

New to This Edition

Just as cloud technology continues to evolve, so does learning science and the insights available to course designers. In the interest of providing you with the most effective and durable learning experience, this latest edition is packed with improvements and enriched features:

- ***Fully updated***—The content maps completely to CompTIA's Cloud+ CVO-003 exam for productive exam preparation.
- ***Module outlines***—Each module begins with a brief outline of the content to help you organize the ideas in your mind as you read.
- ***"Remember This" feature***—Section-specific learning objectives blend the Cloud+ exam objectives with the material covered in each section to help you focus on the most important points of that section.
- ***Self-check questions***—Periodic multiple-choice questions sprinkled throughout the readings help you mentally complete the "learning cycle" as you practice recalling the information as you learn it. With answers and thorough explanations at the end of each module, you can check your own learning and assess your progress toward mastering each module's objectives.
- ***Review questions***—A set of 10 review questions at the end of each module provides exam practice to help you assess the effectiveness of your learning and identify weak areas for further study.
- ***Group activities***—One or more projects in each module offer optional group work activities to enhance the exploration of various concepts and skills.
- ***Capstone projects***—Each module concludes with an in-depth project where you implement the skills and knowledge gained in the module through real design and deployment scenarios. In each Capstone project, you can use the cloud platform of your choice, whether that's AWS, Azure, GCP, or some other cloud platform. You can refer to guidance provided earlier in the module or course, and you can practice applying research skills to figure out how to complete new, related tasks.
- ***Appendices***—New appendices provide exam-to-modules mapping, modules-to-exam mapping, a list of Cloud+ acronyms, and a grading rubric for projects and discussions.

Text and Graphic Conventions

Where appropriate, additional information and exercises have been added to this text to help you better understand the topic at hand. The following labels and icons are used throughout the text to alert you to additional materials.

Note 1

Prolific notes draw your attention to helpful material related to the subject being described and offer expanded insights to enrich your understanding.

Caution !

Occasional Caution boxes alert you to potential issues.

Cloud+ Exam Tip ✔

The CompTIA Cloud+ Exam Tip icon provides helpful pointers when studying for the exam.

Grow with Cengage Unlimited!

Cengage Unlimited boxes provide cross-references to other Cengage materials if you need additional information about a topic.

If you don't have a Cengage Unlimited subscription, you can find more information at cengage.com/unlimited.

Remember This

The Remember This feature highlights important points from each section as you finish reading that material. This invitation to pause and reflect helps you track your learning and ensure you're absorbing the most relevant concepts as you go.

Self-Check

To complete the learning cycle, these self-check questions help you practice recalling the information you've read. With answers and extensive explanations provided to readers at the end of each module, this low-stakes practice testing helps you assess how well you're learning and what material you might need to review before completing graded work.

You're Ready

These action pointers indicate when you've studied the concepts needed for each Hands-On Project at the end of the module. At each point, you can choose whether to take a break from reading to apply the concepts you've learned, or you can keep reading. These forks in the learning path encourage you to actively engage in choosing how you learn best.

Hands-On Projects

Each Hands-On Project in this course is preceded by a description of the project, required resources, and the relevant exam objective. Hands-On Projects help you understand the theory behind cloud with activities using some of the most popular cloud services.

Capstone Projects

Capstone Projects are more in-depth assignments that require a higher level of concept application. By providing less detailed guidance, these projects help you see the "big picture" of what you're learning. They challenge you to demonstrate a solid understanding and application of skills required for the CompTIA Cloud+ exam and a career in cloud computing.

Certification

Each main section of a module begins with a list of all relevant CompTIA Cloud+ objectives covered in that section. This unique feature highlights the important information at a glance and helps you better anticipate how deeply you need to understand the concepts covered.

Instructor's Materials

Instructors, please visit cengage.com and sign in to access instructor-specific resources, which includes the Instructor's Manual, Solutions Manual, PowerPoint Presentation, Syllabus, and Figure Files.

Instructor's Manual: The Instructor's Manual that accompanies this course includes additional instructional material to assist in class preparation, including suggestions for classroom activities, discussion topics, and additional projects.

Solutions Manual: Answers to Review Questions, Scenario-Based Questions, Hands-On Projects, Capstone Projects, Live Virtual Machine Labs, along with rubrics for Cloud for Life and Reflection activities, are provided.

PowerPoint Presentations: This course comes with Microsoft PowerPoint slides for each module. These are included as a teaching aid for classroom presentation, to make available to students on the network for module review, or to be printed for classroom distribution. Instructors, please feel at liberty to add your own slides for additional topics you introduce to the class.

MindTap for Cloud+ Guide to Cloud Computing

MindTap is an online learning solution designed to help you master the skills you need in today's workforce. Research shows employers need critical thinkers, troubleshooters, and creative problem-solvers to stay relevant in our fast-paced, technology-driven world. MindTap helps you achieve this with assignments and activities that provide hands-on practice, real-life relevance, and certification test prep. MindTap guides you through assignments that help you master basic knowledge and understanding before moving on to more challenging problems. MindTap activities and assignments are tied to CompTIA Cloud+ certification exam objectives. MindTap features include the following:

- ***Integrated videos*** are embedded in the module readings to show you concrete skills in four cloud platforms (Amazon Web Services, Microsoft Azure, and Google Cloud Platform). These author-led videos demonstrate skills, tools, and concepts covered in the modules, making abstract concepts and skills more concrete and preparing you to perform similar tasks in the Hands-On Projects. While videos assist in raising your comfort

level with the platform(s) you're using in the projects, you'll benefit from watching videos for all the platforms to develop your expertise with those platforms and deepen your understanding of covered concepts.

- ***Live Virtual Machine Labs*** allow you to practice, explore, and try different solutions in a safe sandbox environment. Each module provides you with an opportunity to complete an in-depth project hosted in a live virtual machine environment. You implement the skills and knowledge gained in the module through real design and configuration scenarios.
- ***Adaptive Test Prep (ATP)*** app is designed to help you quickly review and assess your understanding of key IT concepts. Test yourself multiple times to track your progress and improvement by filtering results by correct answers, by all questions answered, or only by incorrect answers to show where additional study help is needed.
- ***Pre- and Post-Assessments*** emulate the CompTIA Cloud+ certification exam.
- ***Cloud for Life*** assignments encourage you to stay current with what's happening in the cloud industry.
- ***Reflection*** activities encourage classroom and online discussion of key issues covered in the modules.

Instructors: MindTap is designed around learning objectives and provides analytics and reporting so you can easily see where the class stands in terms of progress, engagement, and completion rates. Use the content and learning path as-is or pick and choose how your materials will integrate with the learning path. You control what the students see and when they see it. Learn more at cengage.com/mindtap/.

State of Cloud Computing in IT

Most organizations in nearly every industry rely on the cloud to some degree. The Flexera 2022 State of the Cloud Report (info.flexera.com/CM-REPORT-State-of-the-Cloud) polled 753 IT professionals from a wide range of industries in late 2021. All respondents currently use cloud services at their companies, with 96 percent in the public cloud and 84 percent using a private cloud. Organizations aren't limiting themselves to a single cloud platform, with 89 percent of respondents reporting their organizations employ a multi-cloud strategy. Furthermore, respondents reported that about half of their workloads run in a public cloud, and nearly half their data resides in a public cloud.

According to the same survey, the value of cloud computing shows in these organizations' budgets as well. More than half of the respondents, representing both small and large businesses, report their companies already spend more than $2.4 million annually for public cloud services. Over two-thirds of surveyed organizations report the operation of an existing cloud-specialist team, such as a CCOE (cloud center of excellence), with another fifth planning to create such a team in the near future.

Certifications

While unemployment rates for technology occupations are hitting record lows according to CompTIA (comptia.org/newsroom/2021/08/06/new-hiring-continuing-strong-employer-demand-drive-tech-unemployment-rate-to-its-lowest-level-in-two-years-comptia-analysis-reveals), rising salaries for jobs such as cloud architect, cloud infrastructure engineer, and cloud administrator reveal the soaring demand specifically for cloud computing expertise. According to the Global Knowledge 2021 IT Skills and Salary Report (globalknowledge.com/us-en/content/salary-report/it-skills-and-salary-report/), cloud computing pays more and is in higher demand than nearly any other IT sector, exceeded only by sales and marketing for pay and by cybersecurity for demand. Traditional degrees and diplomas do not identify the skills that a job applicant possesses, especially in relation to fast-changing cloud technologies. Companies are relying increasingly on technical certifications to adequately identify skilled job applicants, and these certifications can offer job seekers a competitive edge in the job market.

Certifications fall into one of two categories:

- Vendor-neutral certifications are those that test for the skills and knowledge required in specific industry job roles and do not subscribe to a vendor's specific technology solutions. Some examples of vendor-neutral certifications include all the CompTIA certifications (comptia.org) and certifications from CSA (Cloud Security Alliance) and (ISC)^2, which is the International Information System Security Certification Consortium.
- Vendor-specific certifications validate the skills and knowledge necessary to be successful while utilizing a specific vendor's technology. Some examples of vendor-specific certifications include those offered by Amazon Web Services (aws.amazon.com), Microsoft (microsoft.com), Google (cloud.google.com), Red Hat (redhat.com), Salesforce (salesforce.com), and Cisco (learningnetwork.cisco.com).

As employers struggle to fill open IT positions with qualified candidates, certifications are a means of validating the skill sets necessary to be successful within organizations. Furthermore, pursuing certifications helps ensure continued job satisfaction and relevance. According to the Global Knowledge report, most respondents reported pursuing training to improve their skill set, to earn a certification, and to seek a salary increase. In most careers, salary and advancement are determined by experience and education, but in the IT field, the number and type of certifications an employee earns also contribute to salary and wage increases.

Certification provides job applicants with more than just a competitive edge over their noncertified counterparts competing for the same IT positions. Some institutions of higher education grant college credit to students who successfully pass certification exams, moving them further along in their degree programs. For those already employed, achieving a new certification increases job effectiveness and satisfaction, which opens doors for advancement and job security. Certification also gives individuals who are interested in careers in the military the ability to move into higher positions more quickly.

What's New with the CompTIA Cloud+ Certification

Now in its third iteration, the CompTIA Cloud+ exam (CVO-003) reflects the maturation of the cloud industry with updated technologies and concepts framed in the larger context of business priorities and existing IT systems. With less emphasis on physical host configuration and much greater emphasis on cloud infrastructure, management, and security, the new exam requires proficiency with standard cloud services that demonstrates a student's understanding and knowledge in cloud networking, security, storage, and maintenance. These concepts are not directly transferrable from the on-premises data center to the cloud but, rather, require an abstraction of functions to a software-defined environment where everything is virtualized and underlying hardware is essentially invisible to the cloud consumer. Common compute, network, security, and storage standards must be reimagined to take full advantage of the cloud's potential. The new CompTIA Cloud+ exam invites candidates to contemplate these ideas more deeply and in ways more relevant to the cloud ecosystem.

The verbs in the exam's objectives indicate the increased depth of knowledge required for this new version of the exam. In the field of educational psychology, Bloom's taxonomy is an industry-standard classification system used to help identify the level of ability that learners need to demonstrate proficiency. It is often used to classify educational learning objectives into various levels of complexity. Bloom's taxonomy reflects the "cognitive process dimension" of learning and understanding that represents a continuum of increasing cognitive complexity, from remember (lowest level) to create (highest level).

There are six levels in Bloom's taxonomy, as shown in Figure A. The first CompTIA Cloud+ exam (CVO-001) was more heavily weighted toward level 2, Understand. Many of that exam's objectives began with the verb *explain* or *identify*. The next exam, CVO-002, contained only one objective at level 2 and was almost evenly distributed across level 3, Apply, and level 4, Analyze. The new exam, CVO-003, shifted again with a slight increase at level 2, Understand, and the heaviest emphasis on level 3, Apply. Many objectives use such verbs as *configure*, *apply*, *implement*, *perform*, or *troubleshoot*, all of which require practical, hands-on skills and greater understanding than what is needed to explain or identify related concepts.

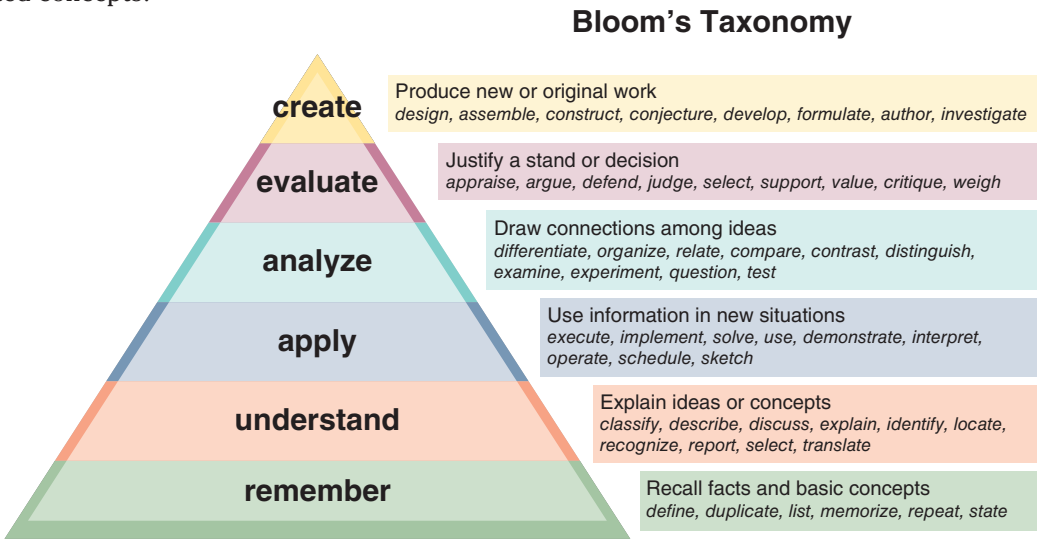

Figure A

In service of demonstrating these hands-on skills, this exam contains many performance-based questions. These questions present simulations with complex interactions designed to test a candidate's ability to apply concepts and analyze problems. Mastering, rather than simply memorizing, the material in this course will help you succeed on the exam and on the job.

Following are the domains covered on the new CompTIA Cloud+ exam:

CVO-003 domain	Percentage of examination
Domain 1.0 Cloud Architecture and Design	13%
Domain 2.0 Security	20%
Domain 3.0 Deployment	23%
Domain 4.0 Operations and Support	22%
Domain 5.0 Troubleshooting	22%

About the Author

Jill West authors Cengage courses for CompTIA Cloud+, CompTIA Network+, Data Communications, and the popular Technology for Success. She has taught kindergarten through college and currently teaches computer technology courses at Georgia Northwestern Technical College. Jill specializes in designing courses that teach to popular IT certifications, and she regularly presents at conferences and webinars on teaching cloud computing and computer networking, and on mentoring lifelong student learners in IT. She is a member of the 2019 inaugural cohort of Faculty Ambassadors for AWS Educate and is an AWS Academy Accredited Educator. Jill and her husband, Mike, live in northwest Georgia with two children at home and two off to college.

Acknowledgments

One of my greatest gifts in life is to get to work with the people who contributed to the development of this book. I've worked with many of these people through multiple projects, and I count them as friends. Lisa Ruffolo manages the numerous moving parts, keeping files flowing to their proper destinations. But more than that, she provides lively encouragement and constructive feedback—I always look forward to reading her comments on each module. Dani Shaw checks every module and project for technical accuracy, and I've come to rely on her eagle eyes to catch mistakes and contribute improvements. Carolyn Mako, though new to the team, jumped right in with insightful suggestions on learning design. I look forward to working with her again in the coming years. Our entire team was fortunate to have Brooke Greenhouse's warm and serene guidance to keep us on track and work her magic when challenges arose. And I'm personally grateful that Natalie Onderdonk continued on our team in her new role at the helm. She will always be one of my favorite geeks ever.

I would like to give a personal "thank you" to all our reviewers who contributed expertise, ideas, insights, and passion: Kim Green (Durham Technical Community College), Allan Pratt (Los Angeles City College), and Jeff Riley

Although my name goes on the cover, what you don't see is the myriad other people diligently contributing, brainstorming, checking, and rechecking to ensure you receive a cohesive and productive learning experience. It truly takes a village to develop an engaging, quality product such as this one.

Thank you to my kids—Winn, Sarah, Daniel, and Zack—for your patience as I work long hours. And thank you to my students for inspiring me to always do better.

A special thanks goes to my husband, Mike West, and all the ways he works tirelessly to keep our household running smoothly, covers the tasks I can't do when flooded with deadlines, and persistently encourages me through the struggles that come with intense schedules and high standards. Mike, I'm so grateful to be doing this life with you.

Read This Before You Begin

Getting into cloud computing is not as difficult as you might initially think. Many cloud providers offer generous free trials, especially for students. In this course, you'll have the opportunity to work in three public clouds: AWS (Amazon Web Services), Microsoft Azure, and GCP (Google Cloud Platform). You can choose any one, two, or all three of these platforms, depending on your needs, preferences, and available resources. They all offer some level of free trial credit and free tier services during the free trial, and some of these options don't even require a credit card if you have a school email account. Module 1 will walk you through the platform options. Regardless of which platform you decide to use, you can read through the material giving parallel information for the other platforms. You can also watch the videos for the other platforms so you can see those cloud services in action.

Finally, the Live Virtual Machine Labs in each module will give you practice with the AWS and Azure public cloud platforms. These labs are accessed through MindTap and let you work in fully functioning virtual machines to build your own cloud resources. With detailed steps and helpful screenshots, you'll find the support you need to perform complex provisioning tasks. Or you can explore and experiment beyond the parameters of the lab because these virtual machines are real systems and not simulations.

As for hardware and software, nearly all the projects in this course are completed through your browser. A decent computer with a good browser such as Chrome, Edge, Firefox, or Safari will work well. You will also need administrative access to your computer: In one project in Module 2, you will install and use VirtualBox, a free hypervisor. For this project, you will also need an ISO file for Windows or a Linux OS. You can instead use a different hypervisor for this project if you prefer. You will also use a drawing app, such as Visio, or you can use a free, online drawing app, such as app.diagrams.net.

These projects have been designed to make the cloud as accessible as possible for students and schools in all kinds of settings and circumstances. Nearly all the projects can be completed for free in their respective cloud platforms, especially if you're still within your free trial limits. Any steps that might accrue charges are identified, along with instructions on how to circumvent charges if you don't have free trial credits available.

Overall, the course offers many layers of options and resources that help you get into the cloud and build hands-on experience, making concepts concrete and memorable while helping you understand and apply the skills you're learning.

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Module 1

Introduction to Cloud Computing

Module 1 Objectives

After reading this module, you will be able to:

1. Explain the primary characteristics of cloud computing.
2. Compare cloud deployment models.
3. Compare cloud service models.
4. Identify popular cloud service providers.
5. Apply troubleshooting methodology.

Module 1 Outline

Study this module's outline to help you organize the content in your mind as you read.

Section 1-1: Characteristics of Cloud Computing
- CompTIA Cloud+ Certification
- Other Cloud Certifications
- What Is Cloud Computing?
- What Do I Need to Know?

Section 1-2: Cloud Deployment Models
- Public Cloud
- Private Cloud
- Hybrid Cloud
- Multi-Cloud
- Community Cloud
- Cloud Within a Cloud

Section 1-3: Cloud Service Models
- Common Cloud Service Models
- Service Model Security Concerns

Section 1-4: Cloud Service Providers
- PaaS and IaaS Providers
- Common Cloud Services
- Internet of Things (IoT)

Section 1-5: Troubleshooting Methodology
- Common Cloud Computing Problems
- Troubleshooting Steps
- Preventive Measures

Module 1 Scenario

The clock says 8:56 a.m. as you slide in through the basement door of your building, shaking the rain off your umbrella and wiping your feet on the doormat. You're right on time for once! You notice the empty boxes still sitting by the doorway after yesterday's delivery of new cabling supplies. When you glance up at the security camera in the lobby area, you wonder yet again who might be sitting on the other side of that camera watching you move through the office space toward your desk. You make a mental note to ask Henry, the security guard at the front gate, where the camera feed goes and how often someone sits staring at the feeds … just out of curiosity, of course.

As you hang your jacket on the back of your chair and prop your umbrella in the corner near your desk, Kendra, your boss, calls out from her office, "Come on, everyone—we've got a meeting!"

Oh, that's right. Your IT team is discussing the upcoming cloud migration today. At the meeting, the CIO of the private school you work for summarizes an Amazon Web Services (AWS) conference he recently attended touting the benefits of cloud computing. He's seeing dollar signs as he excitedly describes all the ways your school can save money by migrating to the cloud. "We won't have to pay so much for IT hardware anymore, our expenses will flex with our changing IT needs throughout the year, and even our electric bill will go down. Plus, the cloud apps we can use in the classroom are good for our students. We'll be able to attract more students from tech-savvy families moving to the area because of the tech start-ups and other IT companies migrating here."

Sounds like a good plan. Now it's up to your team to figure out how to do it. Your cloud conversion team will be led by your boss, Kendra, the network administrator. You've been recruited to help, along with a recently hired co-worker, Nigel, who passed his A+ certification exam last spring while taking night classes and then asked to be transferred to IT from his former position as a security guard. None of you have much experience with the cloud yet, other than binge-watching movies on the weekends and using your personal Gmail and social media accounts. The technology seems a little futuristic and "out there" when you think about it. But you're also secretly excited about learning some new stuff. Supposedly, "the cloud" is the next big revolution in the IT industry, and you'd rather be ahead of the curve than behind it on something so significant.

As the meeting rolls along, the entire team discusses what kinds of information you all need to know to have an intelligent conversation about the cloud. As you wrap up your action list in preparation for your next meeting, the questions you want to answer for yourself are the following:

- What is cloud computing?
- What new skills do I need to learn?
- Who owns the cloud?
- How does the cloud affect the security of my organization's data?

Section 1-1: Characteristics of Cloud Computing

Certification

1.4 Given a scenario, analyze the solution design in support of the business requirements.

CompTIA (Computing Technology Industry Association and pronounced "comp-TEE-uh") released its first cloud computing certification, Cloud Essentials (CLO-001), in 2011 and updated to the current Cloud Essentials+ exam (CLO-002) in 2019. Cloud Essentials+ is intended for non-IT professionals or for IT professionals needing to bridge the gap between technical concepts and business concerns. The more technical Cloud+ certification (CVO-001) was first released in 2015, and the newest version of the Cloud+ certification, CVO-003, launched in mid-2021. While there are

no prerequisites for taking the exam, Cloud+ builds on the knowledge required for other technical certifications (see Figure 1-1), including the following:

- ***CompTIA A+***—Covers skills required for IT technical support specialists
- ***CompTIA Network+***—Covers foundational networking concepts and skills
- ***CompTIA Security+***—Surveys IT security technologies and strategies at a level necessary for any IT professional

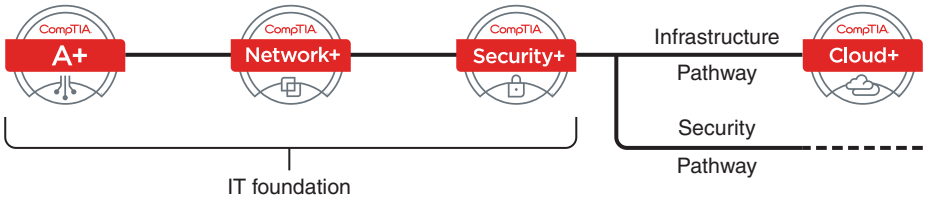

Figure 1-1 CompTIA Cloud+ is an infrastructure-specialty certification

Source: CompTIA, Inc.

While these certifications ("certs" for short) are not required for the Cloud+ exam, the knowledge covered by their objectives is directly relevant to the skills required of a Cloud+ certified technician. Cloud+ takes the foundational concepts covered in these earlier exams and applies that information to a cloud environment. This course assumes you are already at least somewhat familiar with A+, Network+, and possibly Security+ skills and concepts.

CompTIA Cloud+ Certification

One aspect that sets Cloud+ apart from most other cloud computing certs is that Cloud+ is vendor neutral. This means that, throughout this course, you will learn cloud computing concepts that span the full range of cloud computing services rather than targeting specific skills for working with any one cloud provider's platform. You might pursue a Cloud+ certification for the following reasons:

- To prepare for a new job or a promotion that likely will include responsibility for interacting with an organization's existing cloud services.
- To build a foundational understanding of cloud computing in preparation for vendor-specific cloud certifications.
- To complement certifications in other specialty areas (such as infrastructure, security, database management, or programming).
- To develop a big-picture perspective of cloud computing technologies, major players, and industry expectations in preparation for choosing vendors and migrating on-premises ("on-prem" for short) services to the cloud.

Other Cloud Certifications

Another vendor-neutral cloud certification is the more advanced CCSP (Certified Cloud Security Professional) certification from (ISC)², which is the International Information System Security Certification Consortium. The CCSP focuses on the security side of cloud computing at an expert level and requires a minimum five years of paid, full-time IT work experience, three years of which must be in information security and one year in work specific to one or more of the six exam domains. Alternatively, you must already have (ISC)²'s CISSP (Certified Information Systems Security Professional) certification.

Several highly respected, vendor-specific cloud certifications prove increasing levels of proficiency with specific cloud platforms and products. **CSPs (cloud service providers)**—such as Amazon, Microsoft, and Google—invest

significant resources into providing training and certification programs for industry professionals. Some of the major vendor cloud certifications include the following:

- **AWS (Amazon Web Services)** holds the lion's share of the cloud platform market. AWS role-based certifications follow one of several certification tracks or learning paths, such as Architect, Developer, or Operations. Within each path, roles progress from Foundational and Associate to Professional and, in some cases, Specialty levels. Popular AWS certs include the three following certifications:
  - ***Cloud Practitioner***—This nontechnical, entry-level AWS certification is appropriate for professionals in technical, managerial, sales, purchasing, or financial roles.
  - ***AWS Certified Solutions Architect – Associate***—This intermediate AWS cert focuses on designing applications and systems in AWS. The related, advanced cert is AWS Certified Solutions Architect – Professional.
  - ***AWS Certified SysOps Administrator – Associate***—This intermediate AWS cert focuses on creating automated deployments of applications, networks, and systems in AWS. The related advanced cert is AWS Certified DevOps Engineer – Professional.
- Microsoft supports the **Azure** cloud platform and offers the following exam pathways to earn its Azure certifications:
  - ***Microsoft Certified: Azure Fundamentals***—This entry-level Azure certification is appropriate for candidates with nontechnical backgrounds or for technical professionals validating foundational knowledge of cloud services.
  - ***Microsoft Certified: Azure Administrator Associate***—This intermediate Microsoft cert focuses on implementing, monitoring, and maintaining Azure-based cloud solutions.
- **GCP (Google Cloud Platform)** is another major contender in the global cloud market and is quickly growing. While GCP offers fewer certifications, they are highly relevant if you will be working in a GCP ecosystem. Popular GCP certs include the following:
  - ***Cloud Digital Leader***—This nontechnical GCP certification requires knowledge of Google Cloud products and services in addition to basic cloud concepts.
  - ***Associate Cloud Engineer***—This entry-level GCP certification covers setting up, deploying, and securely operating a cloud solution. Google recommends at least six months related work experience before taking the exam.
  - ***Professional Cloud Architect***—This intermediate GCP cert focuses on designing, managing, optimizing, and securing a cloud solution architecture.
- **VMware**, a well-known provider of virtualization solutions, offers solutions that are highly integrated into some public cloud platforms. The following are two VMware cloud certs:
  - ***VMware Certified Technical Associate – Cloud Management and Automation***—This entry-level cert demonstrates a basic understanding of virtualization and cloud concepts.
  - ***VMware Certified Professional***—This intermediate exam requires skills to install, configure, and administer the VMware cloud environment.

Note 1

An entry-level cloud computing job might be called a junior cloud engineer, cloud implementation manager trainee, cloud technical architect, or junior cloud analyst, among many other possibilities. More advanced cloud computing positions might go by titles such as CSA (cloud systems administrator), senior cloud engineer, or cloud infrastructure engineer.

What Is Cloud Computing?

What makes cloud computing so attractive to companies looking to maximize their bottom line? According to **NIST (National Institute of Standards and Technology)**, cloud computing has five essential characteristics, as shown in Figure 1-2:

- ***On-demand self-service***—In a traditional network or data center setting, network resources must be carefully planned, purchased, configured, and implemented. It can take months after deciding to institute a new

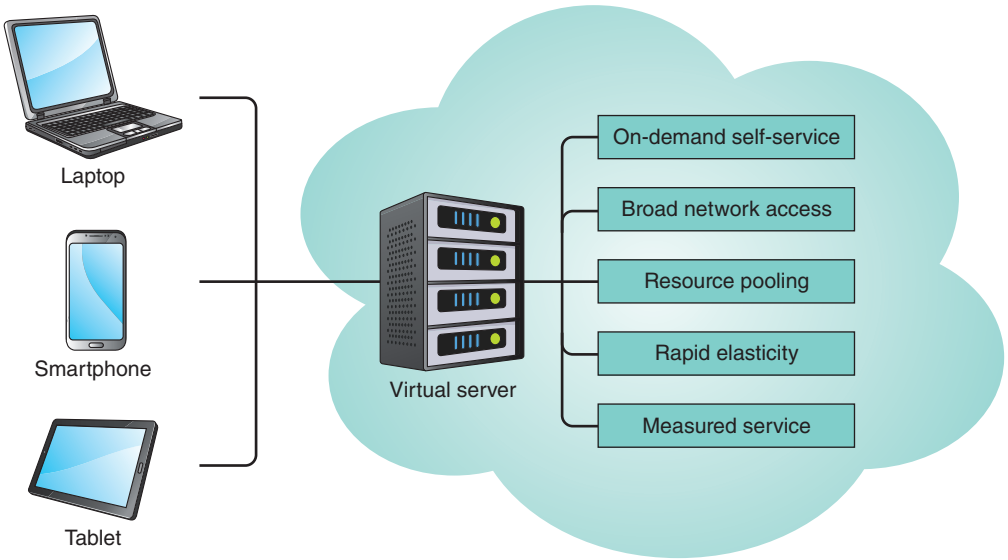

Figure 1-2 Characteristics of cloud computing

resource until that resource becomes available. Many people are typically involved in the decision-making and implementation processes. In contrast, cloud resources, such as VMs (virtual machines) or user accounts, can be created at any time by the service subscriber and other authorized users, which is called **on-demand self-service**. There's no built-in delay to order, install, and configure hardware because cloud resources are virtualized on top of existing hardware at the service provider's location. For example, suppose you need to add a web server to your network. Within a few minutes, you can spin up a VM in the cloud; optimize its virtual hardware resources (such as memory and processing power) and network settings to support web services; and then install the web server software, website files, and content to produce a live website. This process, once established, can even be automated.

- ***Broad network access***—Traditional network resources are mostly available only to users located within a specific geographic area. To access and configure these resources from outside the network, the user must "remote in" using a **VPN (virtual private network)** connection or similar remote access technology. Cloud services, however, can be accessed and configured from anywhere on the Internet and using any of a number of device types, such as a laptop, smartphone, or tablet. This type of access is called **broad network access**, and it gives cloud computing the flexibility of access to a larger user population in a wider variety of circumstances.
- ***Resource pooling***—In traditional networks, physical and virtual resources reside at the organization's own location, and all those resources are dedicated to the organization's own use. If a server is functioning at 10 percent capacity to meet the organization's needs, the remaining capacity is simply unused. Cloud providers use **resource pooling** to maximize the potential capacity of physical and virtual resources, which simultaneously serve multiple customers—called **tenants**—at any given time. The cost benefits of this efficiency are passed along to customers. A single server might be performing compute operations for three or four different cloud subscribers, and a single subscriber might be running a database whose data is held by multiple servers at multiple locations owned and operated by the cloud provider. In most cases, cloud customers don't know where their resources are hosted geographically; they only know how to access them through the Internet. Resource pooling is made possible by **multitenancy**, which means to support multiple customers' processes running on the same hardware. Multitenancy maximizes the potential capacity of physical and virtual resources by simultaneously serving multiple customers.
- ***Rapid elasticity***—**Rapid elasticity** refers to a cloud resource's ability to be added, released, increased, or decreased quickly—even automatically—according to demand. For example, suppose your company is preparing to run a Super Bowl ad and anticipates a tremendous increase in traffic to their website. On a traditional network, you would need to order additional servers to help support the increased traffic. This could take weeks of preparation and would be very expensive. After the ad traffic subsided, you would be left with several servers whose purpose had waned. If your web server is hosted in the cloud, however, you could provision

additional web servers in minutes—or program them to auto-provision as needed—and then decommission those servers as the ad-generated traffic tapers off. You would only pay for the cloud servers while you used them, and once decommissioned, you would incur no additional costs.

- ***Measured service***—The ability to track your usage of cloud resources at a granular level is what makes cloud computing a **measured service**. You are charged for the resources you use. Many cloud providers allow for detailed tracking of these activities and charges. For example, AWS bills for VM instances by the second, which avoids costly roundups to full-minute or hourly pricing. This pay-as-you-go approach, if configured properly, can save companies a great deal of money even before other optimizations are made for cloud technology.

Cloud providers often describe additional characteristics and benefits to cloud computing, including the following:

- ***Self-patching/self-healing infrastructure***—Because much of cloud computing is automated, a cloud network can patch or repair itself when encountering certain types of problems.
- ***Adaptive, intelligent security***—Cloud computing increasingly takes advantage of AI (artificial intelligence) technology to improve built-in security defenses.
- ***Cross-platform***—Cloud services can be accessed and used from devices running different OSs (operating systems).

Organizations consider many reasons for transitioning to a cloud environment. They might be facing the expiration of a lease at their data center location; they might be looking for ways to optimize their services and become more competitive; or they might expect that cloud services will improve their bottom line. The cloud transition is not an overnight shift—organizations adopt cloud services in phases, and many will never become fully cloud-centric. Even after they've begun to make the transition to the cloud, business and user needs continue to change, and so do their cloud service requirements. Whether the changes are external, such as changes to regulations or laws, or internal, such as business mergers (two businesses blending into one), acquisitions (one business buying another), or divestitures (one business splitting off part of itself), the cloud services that support the business will need to be adapted, migrated, or replaced. All these changes require specialized skills from IT technicians to configure, deploy, secure, maintain, manage, and troubleshoot cloud computing services and resources.

What Do I Need to Know?

Cloud computing is a fairly recent—and rapidly changing—development in IT that is simultaneously revolutionizing the industry. Skills and knowledge from even five years ago are insufficient to meet the demands of managing today's cloud-hosted resources. IT professionals throughout the industry are asking what new skills will help them stay relevant as cloud computing technologies emerge and mature. The following list shows areas of professional growth most needed for cloud computing professionals—or any IT professional interacting significantly with the cloud:

- ***Security skills***—Traditionally, IT security focuses on maintaining a protective perimeter around the on-prem data center, managing all traffic into and out of that secure perimeter (see Figure 1-3). As data, applications, and other resources move to the cloud, security must be built into the resources themselves so it travels with each resource. Administrators must also carefully consider what data can be outsourced to the cloud, as some types of regulated data are restricted to on-prem storage only. At the same time, cloud service providers offer options with built-in security compliance measures, which can relieve customers of needing to configure these requirements themselves. While the cloud customer is still responsible for enabling cloud security measures and configuring them in ways that best fit their needs, most cloud providers offer many tools—some that are free—to help with this effort. A cloud IT professional must become familiar with these tools and best practices in using them.
- ***Cross-discipline expertise***—The broad possibilities inherent in cloud computing require that cloud technicians understand the business and organizational context of the services provided through the cloud. The more you understand, the more valuable you'll make yourself to potential employers. Important areas include the following:
  - The organization's business goals and the business processes and workflows that affect every department within an organization
  - Software development processes, including automation, configuration management, virtualization, monitoring, and CI/CD (continuous integration/continuous delivery)

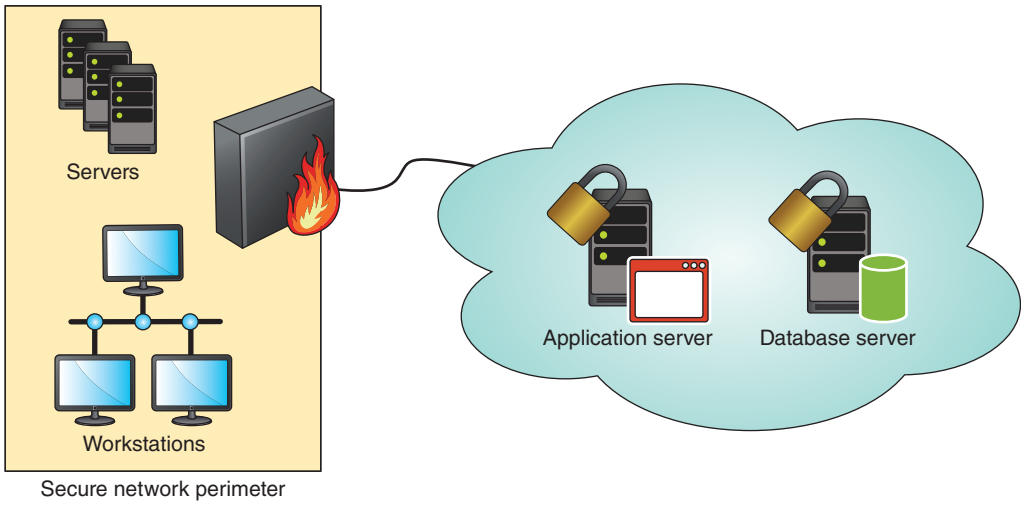

Figure 1-3 Cloud security can't rely on a secure perimeter

- Infrastructure concepts, skills, and tools—networking in the cloud transitions the concrete configurations of a local network into a more abstract layer, which will only make sense to you if you thoroughly understand local networking
- Security vulnerabilities, technologies, and best practices that are specific to cloud-hosted resources

- ***Automation scripting skills***—One of the biggest advantages of moving to the cloud is gaining a greater degree of **automation**. The underlying virtualization layer and the encompassing monitoring techniques allow for granular and responsive automation. Developing the skills required to script extensive automation processes (called **orchestration**) in a way that is both efficient and reliable, and then continuing to refine them, is where cloud network admins often are most challenged.
- ***Lifelong learning***—Cloud technologies are in constant flux, even more so than on-prem technologies. CSPs are innovating at an astonishing rate. A service that adequately meets your needs when you first migrate to the cloud could be overshadowed by a much improved—and cheaper—service a few months later. Staying relevant requires monitoring your own learning by identifying your blind spots, finding the information resources you need, and following through on your learning process. The most important computer skill is the ability to teach yourself.

You're Ready

You're now ready to complete Project 1-1: Research Cloud Computing Certifications. You can complete the project now or wait until you've finished all the readings for this module.

Remember This

- The CompTIA Cloud+ certification is a vendor-neutral, entry-level cloud computing certification that requires demonstration of technical skills.
- Popular cloud vendor certifications are published by CSPs such as Amazon, Microsoft, and Google.
- Cloud computing consists of five essential characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service.
- Skills most needed by cloud professionals include security skills, cross-discipline expertise, automation scripting skills, and lifelong learning.

Self-Check

1. Which cloud platform does the CompTIA Cloud+ certification target?
   a. AWS
   b. Azure
   c. GCP
   d. None

2. Which of these certifications requires the least technical skill?
   a. CompTIA Cloud+
   b. Associate Cloud Engineer
   c. AWS Cloud Practitioner
   d. VMware Certified Professional

3. Which of the following is NOT an essential characteristic of cloud computing?
   a. Adaptive security
   b. Broad network access
   c. Rapid elasticity
   d. On-demand self-service

Check your answers at the end of this module.

Section 1-2: Cloud Deployment Models

Certification

1.1 Compare and contrast the different types of cloud models.

1.3 Explain the importance of high availability and scaling in cloud environments.

1.4 Given a scenario, analyze the solution design in support of the business requirements.

2.4 Given a scenario, apply data security and compliance controls in cloud environments.

One advantage of cloud computing is that a business can use someone else's hardware to host its applications, data, and network infrastructure. One disadvantage of cloud computing is that a business must typically rely on someone else's hardware to host its applications, data, and network infrastructure. Those statements aren't redundant or contradictory—cloud computing adds convenience while also reducing an organization's control of the hardware supporting their IT resources. This creates specific security concerns that vary according to the type of cloud services an organization decides to use. Most organizations don't jump directly into a cloud-only deployment, so you should be aware of the various options for who owns what resources in the cloud and how various security responsibilities are distributed between the CSP and cloud customer.

Public Cloud

When people think of cloud computing, the public cloud is generally what they have in mind. As shown in Figure 1-4, **public cloud** services are hosted on hardware resources at the CSP's location, and those physical resources can be shared with any other customer. The CSP might be a business, an academic organization, or a government entity. It provides cloud services (paid or free)—such as storage space, applications, compute capacity, or network functions—that are available to the general public.

With a public cloud, the CSP manages the hardware, which can't be accessed directly by the cloud customer. In this case, the customer relies deeply on the CSP's security measures to protect the data and other resources hosted in the public cloud. However, this doesn't mean the customer has no responsibility for its data security or that all CSPs

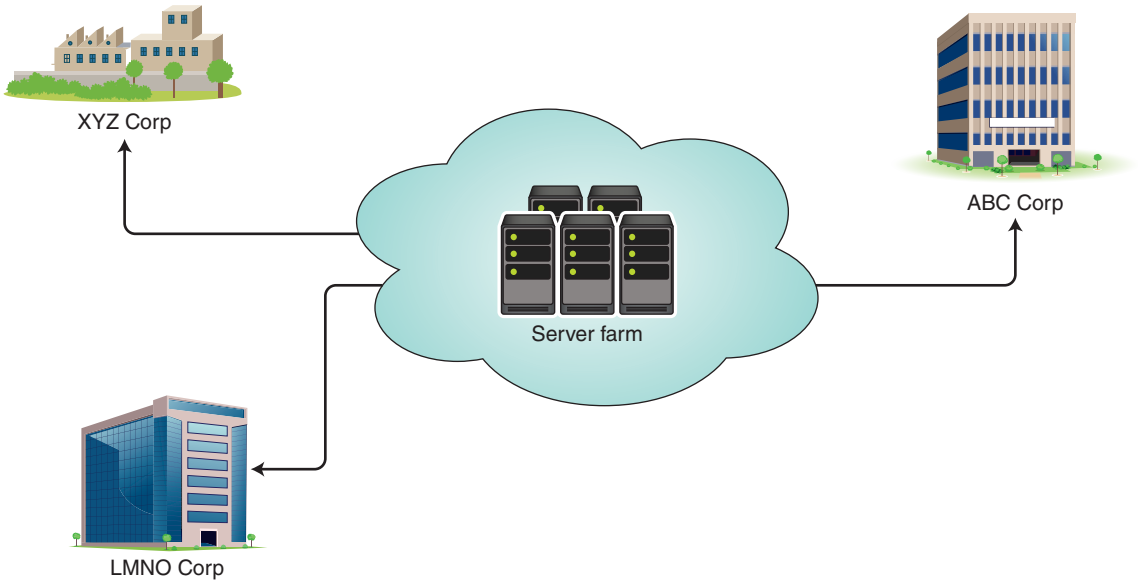

Figure 1-4 A public cloud is hosted on hardware shared by multiple customers

provide sufficient data center security. The following is a list of steps public cloud consumers can take to help ensure the security of their public cloud and its compliance with relevant industry standards:

- Research the CSP's industry certifications and audit compliance reports. Some of the most important to look for include the following:
  - ***ISO/IEC 27001***—Developed by the ISO (International Organization for Standardization) and the IEC (International Electrotechnical Commission), the **ISO/IEC 27001** standard provides an overarching model for organizations to use in keeping information secure. It addresses people, processes, and IT systems through a risk management process; all these components together are referred to as an ISMS (information security management system). An organization can become ISO/IEC 27001 certified by meeting these requirements, as determined by an audit conducted by an accredited certification body. Learn more about this certification at iso.org/isoiec-27001-information-security.html.

Note 2

The ISO (International Organization for Standardization) is an independent, nongovernmental international organization established in 1947 and is also responsible for having developed the seven-layer OSI (Open Systems Interconnection) model used in networking. Its shortened name, ISO, is derived from a Greek word meaning equal. The organization's founders chose this abbreviation to avoid confusion from having various acronyms for their name, depending on the language used.

  - ***SSAE 18***—The **SSAE (Statement on Standards for Attestation Engagements No. 18)**, developed by the AICPA (American Institute of Certified Public Accountants), is a standard used to determine audit compliance. The SSAE 18 replaced earlier standards such as SSAE 16, which replaced an even older standard, SAS 70 (Statement on Auditing Standards No. 70). Additional amendments continue to be made to the SSAE 18 where later releases, such as SSAE 19, replace certain portions of SSAE 18. Instead of resulting in a certification, an SSAE 18 audit results in various **SOC (Service Organization Control) reports**. Two types of SOC 1 (pronounced sock one) reports focus on internal financial controls. Most relevant to this discussion, however, are the SOC 2 and SOC 3 reports. Both reports address benchmarks as defined by the organization for information security, availability, processing integrity, confidentiality, and privacy. The SOC 2 report contains proprietary information and often requires a signed **NDA (nondisclosure agreement)** before release to a